DEPARTMENT OF COMMERCE
BUREAU OF STANDARDS
George K. Burgess, Director

TECHNICAL CONFERENCE OF STATE UTILITY COMMISSION ENGINEERS

MARCH 2 AND 3, 1923

MISCELLANEOUS PUBLICATIONS—No. 58

DEPARTMENT OF COMMERCE
BUREAU OF STANDARDS
George K. Burgess, Director

MISCELLANEOUS PUBLICATIONS No. 58

TECHNICAL CONFERENCE OF STATE UTILITY COMMISSION ENGINEERS

HELD AT THE BUREAU OF STANDARDS
WASHINGTON, D. C., MARCH 2 AND 3, 1923

PRICE, 15 CENTS
Sold only by the Superintendent of Documents, Government Printing Office
Washington, D. C.

WASHINGTON
GOVERNMENT PRINTING OFFICE
1924

LIST OF ENGINEERS ATTENDING CONFERENCE

The following engineers of public service commissions were in attendance at the conference:

I. F. McDonnell, Alabama.
A. E. Knowlton, Connecticut.
J. Houstoun Johnston, Georgia.
Earl L. Carter, Indiana.
A. B. Campbell, Iowa.
Wm. M. Black, Maine.
H. C. Wolf, Maryland.
W. F. Strouse, Maryland.
S. A. Covell, Maryland.
J. A. Cullen, Maryland.
L. Ellis, Maryland.
R. Y. Gildea, Maryland.
J. L. Wicks, Maryland.
Manfred K. Toeppen, Michigan.
D. Waldo White, New Hampshire.
Philander Betts, New Jersey.
C. R. Vanneman, New York.
R. H. Nexsen, New York.
Ward Snook, Ohio.
A. I. Thompson, Oklahoma.
James Imboden, West Virginia.
C. B. Hayden, Wisconsin.
E. G. Runyan, District of Columbia.

CONTENTS

	Page
Foreword	1
First Session (Morning of Friday, March 2, 1923)	
Opening address, by Secretary Herbert Hoover	2
Public-utility work of the Bureau of Standards	3
Electrolysis and its mitigation, Burton McCollum	4
Safety engineering and safety codes, M. G. Lloyd	4
Gas engineering, W. M. Berry	4
Electric light and power service standards, J. F. Meyer	5
Telephone service standards, F. A. Wolff	5
Discussion	5
Grading utilities on conformity to service rules, by C. B. Hayden, service engineer, Railroad Commission of Wisconsin	7
Grading of public utility service, by J. Howard Mathews, service engineer, Illinois Commerce Commission	19
Second Session (Afternoon of Friday, March 2, 1923)	
Discussion of papers on grading of utilities	24
General review of the inductive interference problem, by Burton McCollum	28
Discussion of problem of inductive interference	40
Grounding of electrical circuits, by M. G. Lloyd	48
Discussion of grounding of electrical circuits	49
Third Session (Morning of Saturday, March 3, 1923)	
Discussion of grounding of electrical circuits (continued)	53
The public interest in heating value standards for gas, by S. A. Covell, assistant engineer, Maryland Public Service Commission	55
The public interest in heating value standards for gas, by C. R. Vanneman, chief engineer, New York Public Service Commission	59
Discussion of papers on heating value standards for gas	64
Report of committee on organization	68
Conservation of natural gas, by James Imboden, chief engineer, West Virginia Public Service Commission	69
Conservation of natural gas, by Ward H. Snook, inspector, power wire, Ohio Public Utilities Commission	74

TECHNICAL CONFERENCE OF STATE UTILITY COMMISSION ENGINEERS

HELD AT THE BUREAU OF STANDARDS, WASHINGTON, D. C., MARCH 2 AND 3, 1923

FOREWORD

For more than 10 years the Bureau of Standards has been giving active study to various problems connected with the operation and regulation of public utility services. This work has been done in cooperation with utility companies, as well as city and State officials who are concerned with these problems, but as the practice of exercising control of utilities through State commissions has spread, the bureau's relations with such commissions have naturally become more and more important. While these relations have been very cordial and mutually helpful, it has become evident that there should be provided a more effective means of cooperation between the bureau and the engineers of the various commissions. It has also been recognized as very desirable that engineers of commissions have some regular means of making contact with each other and discussing problems of mutual interest.

In connection with the revision of the National Electrical Safety Code, representatives from seven State commissions visited the bureau in December, 1922. This opportunity was taken to hold an informal meeting to consider the best method of procedure for calling a larger conference. In accordance with decisions then reached, arrangements were made for a general conference of State commission engineers to be held at the Bureau of Standards.

This conference met March 2 and 3, 1923, and its proceedings are herein reported in abbreviated form. It is hoped that this partial report will serve to give a wider usefulness to the important papers presented at the conference.

One of the most valuable features of such meetings is the opportunity to compare experience gained in different localities. In the judgment of those who attended this conference its success justified plans for future meetings of a similar nature at which some sessions should be devoted to problems in which the commissions and the bureau have a joint interest, while others might be assigned to matters with which the commission engineers must deal, but which fall outside the province of the bureau. As is indicated in this report, a representative committee was appointed to arrange for the next meeting without creating any formal organization. The bureau has been glad to have the opportunity of inaugurating these meetings, and trusts that they will develop into an effective means for furthering cooperation in the technical and engineering work of the various commissions.

GEORGE K. BURGESS,
Director, Bureau of Standards.

FIRST SESSION (MORNING OF FRIDAY, MARCH 2, 1923)

The first two sessions of the conference were held at the Department of Commerce Building. The opening session was called to order at 10 o'clock by Secretary Hoover, who spoke as follows:

GENTLEMEN: You are responsible in some measure for calling this conference. It has been suggested by utility engineers that some such conference should be called, and it is the policy of this department in all matters to endeavor to set up measures of cooperation with various bodies with which the department must come in contact in one way or another. We have a feeling that the field of utility regulation presents many problems that must be solved by joint action. This department has no regulatory authority of any consequence. It is not looking for authority. It is looking for the best solution of engineering problems by means of cooperation with other public service bodies. The problems that you have to deal with are problems of an intensely technical character, but they have a very definite bearing on public utility service and must have translation into engineering terms, and ultimately into money. If we can organize some sort of definite basis of cooperation, we shall feel that we have made material advancement for both sides.

You will, of course, understand that the Bureau of Standards has two separate functions, not very precisely defined, but the first of these is in the field of standardization and the second in the field of research on physical questions. Its work in standardization or determination of various standards, units, and conditions of their use is familiar enough to you. As this industrial country of ours goes on inventing one thing after another, the engineers have to go on with the work of standardization. This is the basis not only of technology but also of the protection of the public. The units and standards used in the measurement of gas and electricity, as well as conditions of their use when applied to all sorts of public utilities, require a certain amount of conference and consideration, because many of these units must be translated into charges.

There are also the other matters of investigation and research. The research problems go into questions of the best mixture of gas, electrical inductive interference of various kinds, electrolysis, and other problems of this nature on which the bureau is constantly engaged, and that research work largely comes up to us from the public utility organizations, from the operating corporations, as well as the States and municipalities. Often, in fact, the bureau is called on to act as advisor in questions of this character, more particularly with the public utility commissions than any other bodies.

We have thought then from the many cases where the bureau has been called upon to act as a sort of umpire by various commissions and others that it would be well if we could have this conference and general discussion, in order that we may have a better basis of cooperation with you—the engineers of these commissions. I want to express my appreciation for your coming here and meeting with

us. We are all more or less interested in engineering problems, and the Bureau of Standards is fundamentally an engineering organization. I feel that whenever and wherever it is possible to do so, we should endeavor to develop the foundations of engineering themselves. I do not believe any engineers' conference is fruitless, because by the needs of their profession and by the character of their work, engineers are men who deal in concrete and constructive thought and waste fewer words and come more definitely along the road of progress than any other group.

I have often been impressed with the exceedingly wide difference between the engineering mind and the economic and political mind. This department has to deal with economic problems to a very large degree and there has resulted a tremendous discussion of pure and applied economics, but the tendency of all economists and economic science is to be purely qualitative. There is very little weighting of their arguments in proportion to the dollars and cents involved.

Nine-tenths of all our problems are economic, but the economist continues to weight the importance of a problem and the force of an argument by a sort of relativity of the quantity of paper on which it is written, whereas the fact is that 99 per cent of the weight may be on the side of the one argument. The engineer is the only man that ever has weighted these economic questions with actual quantities and actual values. He is the only man that has applied engineering to economics. We are all of us dealing often enough with economic problems as well as problems in engineering construction and others of that character. We are, by necessity of our profession and the application of engineering methods to individual and national life, beginning to make a dent in the thought of economists. If we can advance the solution of these economic problems, either through legislation or otherwise, with a little engineering science we will have made pretty definite progress.

This is to be a wide open conference to see whether we can be of assistance to you with the greatest physics laboratory and physics organization in the country, and the engineers that have to apply physics in their relationship to public questions. With this I give you a word of welcome and hope that you may make some progress. Thank you.

PUBLIC UTILITY WORK OF THE BUREAU OF STANDARDS

Mr. E. C. Crittenden, chief of the electrical division of the bureau, gave a brief history of the development of the bureau's work relating directly to utility service problems, his conclusions being as follows:

In brief, in all the work mentioned the bureau has aimed to do three things—first, to carry out experimental investigations of problems affecting the efficiency of operation, cost, and quality of service rendered; second, to determine the facts with regard to actual practice; and third, to combine the results of laboratory investigations and of field observations with the judgment of trained and experienced engineers so as to formulate recommendations or codes of practice which would safeguard the interests both of utility operators and of utility customers.

It should be emphasized that the bureau does not seek nor desire any authority to impose its findings on others. Its position as an impartial fact-finding and advisory body is believed to be the most useful one for a Federal Government agency in this field. Such success as the work has attained in the past would have been impossible without the cordial cooperation of all interests concerned, including utility companies and their associations, as well as city and State authorities. The earlier work was done largely with city officials, but as the principle of State regulation has gained wider and wider acceptance, our contacts have naturally shifted to the State commissions.

More detailed explanations of five of the subdivisions of this work were then given by the men in charge of the respective sections.

ELECTROLYSIS AND ITS MITIGATION, BY BURTON McCOLLUM

Mr. McCollum emphasized the necessity of cooperation of many interests in dealing effectively with this complex problem, and explained how such cooperation of utility interests with the bureau had been obtained through the American Committee on Electrolysis.

In order to determine the most effective means of reducing damage by electrolysis, it became necessary to find better methods for determining what the actual conditions of current flow were. Recent work of the bureau has, therefore, been directed largely toward the development of new methods of electrolysis testing. This development has been so successful that field research work has lately been resumed with a prospect of obtaining much more definite and conclusive results than were previously possible.

Because of its close connection with electrolysis research, corrosive action of soils on pipes and cables is also being studied on a large scale by the same section in the bureau. Manufacturers of materials, as well as utility operators, are cooperating, and representative samples have been buried in 46 typical soils distributed throughout the country. This work will require a number of years, but should eventually make it possible to select more intelligently pipe material that will be most economical for use in a given soil; protective materials are also being tested.

SAFETY ENGINEERING AND SAFETY CODES, BY M. G. LLOYD

The most important item in this work which is of direct interest to utility commissions is the National Electrical Safety Code, particularly those parts dealing with construction of transmission and distribution lines and the grounding of lines and equipment. These parts of the code are now undergoing revision by a committee, which will also draw up specifications covering electrical construction at crossings of all utilities.

A pictorial edition of the code and an engineering handbook covering line construction are also being prepared.

GAS ENGINEERING, BY W. M. BERRY

Gas-service regulations constituted the first specific utility work of the bureau, and Circular No. 32, Standards for Gas Service, which

is now in its fourth edition, has found very extensive use. More recent work of the bureau has been directed toward greater safety and efficiency in the use of gas.

ELECTRIC LIGHT AND POWER SERVICE STANDARDS, BY J. F. MEYER

In this field likewise Circular No. 56, Standards for Electric Service, has been found useful by many commissions. The second edition, now in press, has been prepared with the most cordial cooperation of utility associations, commissions, and city authorities.

A circular, somewhat similar, on "Street lighting" is being prepared, and some progress has been made on rules for central station heating.

TELEPHONE SERVICE STANDARDS, BY F. A. WOLFF

The development of standards for telephone service is an intricate problem which few of the commissions have yet actively taken up, and it is one of the most recent of the bureau's undertakings in the utility field. The work done up to the present time has been largely studies of fundamental principles underlying the telephone art, collection of detailed information regarding telephone practice in various sections of the country, and the analysis of telephone service from the standpoint of standards of service. These studies constitute a groundwork for the determination of standard measures for quantity and quality of service.

Since October, 1921, a large part of the time of the telephone section has been spent on a survey of the Government's own telephone service in the District of Columbia. Through this survey, which has been made under the direction of the Bureau of the Budget and with the cordial cooperation of the company rendering the service, annual economies of $60,000 have been effected with no detriment to the service. The survey has also given the staff exceedingly valuable information regarding many details of telephone equipment and practice.

DISCUSSION OF REPORTS PRESENTED BY BUREAU STAFF

Mr. Toeppen. I note that in all these statements of the bureau's work no mention has been made of problems involving rates and rate groupings or rate structures, nor are these problems included in the program for the conference. These questions are among the most urgent ones before the commissions, and it appears to me that this meeting offers a good opportunity to discuss them. Would it not be well also for the bureau to take up a study of the technical aspects of rate systems? In my judgment this work would be of very great value, especially to the smaller utility companies as well as to the commissions.

Mr. Crittenden. This is a question which has been much discussed in years past. The bureau has deliberately refrained from extending its work into the field of rates because there has been at least a divided opinion on the part of the general public as to the advisability of the bureau's doing this kind of work. To undertake it

would be a definite change of policy on the part of the bureau, and whether or not such a change would be made would depend on the unanimity of the demand for it. We, as public servants, feel that we should do the things that the public asks us to do and which we are qualified to do. If there were a general feeling on the part of those we serve that the bureau should undertake work on rate systems, the bureau might do so, but it must be with the approval and at the request of the interests whose cooperation we would need to have before we could undertake the work with any propspect of success.

Mr. Knowlton. I think the gentleman from Michigan has brought out a point of interest to all of us. There are some important questions upon which the commission engineers would like advice, which are not included in the present program. Perhaps we could stop for a moment and discuss some of these. I think it would be very helpful to get the commission engineers to organize, as loosely or as closely as might be desirable, in order to furnish a basis for the study of these very things.

Mr. Crittenden. We have called this conference to find out just how we can best help you, and whether future meetings are desirable. Regarding the question of organization in this particular, we decided to omit it from the formal program because it was deemed better to find out first the sentiment of the engineers in regard to this matter. This was done, however, with the understanding that if the engineers desired to organize and have future meetings, the bureau would be very glad to cooperate. In this way questions in which you are interested could be scheduled for discussion even though they were outside the scope of the bureau's work .

Mr. Imboden. From what I have seen of the correspondence calling this conference together I have not been able to determine its object other than to discuss these fixed subjects that are on the program. In line with the remarks which have been made I think it would be well, either through the help of the men I might know or through the help of the bureau, to carry this thing further and to have future conferences or have an association.

Mr. Crittenden. The chief business of this conference is to get an understanding between ourselves and yourselves as to just what the bureau can best do. It has not been definitely decided whether we will continue to have these conferences in the future or not. That depends on you. We at the bureau would certainly be glad if this might be the inaugural one of a series of conferences held, perhaps, annually either here in Washington or at other places more convenient for other engineers. Some sort of organization might be formed to make plans for future meetings. You all know, of course, that matters in which the utility commissioners are most directly interested are effectively handled by their own national organization, but our contact being more with engineers and our needs being to get in touch with them, we have felt that a meeting of engineers separately from the commissioners would be a very great advantage to us, and we think it would be an advantage to the engineers themselves. Whether an organization should be formed or not is for you to decide. Our purpose would be to do whatever is of most help to you. I think it would be well for you to appoint a committee to decide if some more or less definite arrangements

can be made for future meetings and to outline the work which it would be desirable for the organization to undertake.

After considerable informal discussion, it was moved by Mr. Knowlton that the Chair appoint a committee of four or five to get together and report back to the conference as to the advisability of forming an organization, with the idea that this committee get thoughts and ideas from other members present and put something definite before the conference.

The motion was carried unanimously. The following were named on this committee: Messrs. Hayden (chairman), Wolf, Thompson, Black, and Meyer.

Mr. CRITTENDEN. We will now pass on to the subject of grading of public utilities. The first paper on this subject will be presented by Mr. Hayden.

GRADING UTILITIES ON CONFORMITY TO SERVICE RULES

By C. B. HAYDEN, *Service Engineer, Railroad Commission of Wisconsin, Madison, Wis.*

The first order issued by the Railroad Commission of Wisconsin prescribing certain requirements for gas and electric service was made effective in 1908; the second order, which is now in effect, was issued in 1913. Very soon after the last order came out, early in 1914, the service department began grading the gas and electric utilities and about a year or so later, in 1915 or 1916, the telephone utilities were given standings. Up to this time we have not attempted to grade the water utilities, although service rules have been in effect for about four years. There does not appear to be any great advantage, as far as our department is concerned, in applying grades to the service of water utilities, since the quality of service with different municipal and private utilities does not vary to any large extent.

When this system of grading was started, it was not with the thought of applying to the regulation of utilities the time-tried plan of grading as used in our school system, where it is absolutely necessary in order to keep the pupils placed according to the achievement and growth which each one makes; nor was it our intention that each utility would be expected to run the gamut of conditions, passing and honor marks through the various years of the course, with the possibility of failure up to the final graduation. It was done because it afforded a means of keeping track of the utilities according to the service standards which had been established and if possible to determine whether there was any increase or decrease in the degree of compliance, from year to year, of the utilities throughout the State or of any one in particular.

After use in this way for some time it was determined to try out the scheme on the unsuspecting utilities, and it was found that the results were decidedly good. The utilities which received high rank were very much pleased and in most every case put forth effort to improve their position or maintain it at any event. To be sure, some jealousy developed, but for the most part the best of feeling existed and a friendly rivalry developed for the high-rank positions.

The engineers present will see that the rules do not all have the same relation to the quality of the service, as, for instance, the meter-

history record has no particular bearing on service, while the pressure conditions and meter-testing practice will determine in a large measure the satisfaction to the consumer.

You will also realize that some of the rules are subject to quite a wide interpretation, and the inspector must make this decision. To be sure that this will be worked out uniformly by the engineer inspectors (all of our inspectors are engineer college graduates), conferences have been held about twice a year, when sample inspection reports are given; that is, each rule is given a percentage by each inspector according to the report. These marks are then compared and the differences argued out by the several inspectors until it is possible to have very good uniformity.

In order to avoid too great variation, the different rules are divided, where this is possible, into their elements, and a portion of the percentage allowed for each subdivision. In the detailed explanation of the markings this will be followed out. The weighting of the various rules for gas and electric service was decided after a number of conferences of all the inspectors, and we believe that the result is reasonably proper.

For gas service the heating value of the gas is given first place in importance, pressure variation second, periodic meter tests third, accuracy of meters and calorimeter equipment fourth, and the balance of the rules of about equal value. For electric service, interruptions and voltage variation hold first place, periodic tests second, accuracy of meters third, and the balance of the rules of about equal value. The following table gives a clear idea of the plan.

TABLE 1.—*Rules regarding gas and electric service*

Rule		Subject	Credit		Credit	
Gas	Electric		Gas	Rank	Electric	Rank
			Per cent		*Per cent*	
-------	14	Creeping meters	-------	-------	4	6
1	15	Accuracy of meters	7	4	7	3
------	16	Installation tests	-------	-------	5	5
2	17	Periodic tests	14	3	14	2
3	18	Meter-testing records	5	6	5	5
4	19	Meter-testing equipment	5	6	5	5
5	20	Request tests	4	7	4	6
6	21	Referee tests	-------	-------	-------	-------
7	22	Meter readings on bills	4	7	4	6
8	-------	Heating value	21	1	-------	-------
9	-------	Calorimeter equipment	7	4	-------	-------
-------	23	Interruptions	-------	-------	18	1
-------	24	Station records	-------	-------	6	4
10	25	Pressure and voltage variation	18	2	18	1
11	26	Pressure and voltage surveys	6	5	6	4
12	-------	Purity	4	7	-------	-------
13	-------	Complaint records	5	6	-------	-------
-------	27	Information	-------	-------	4	6
		Total	100	-------	100	-------

It is obvious that the instance would be rare of a utility which could give perfect voltage or pressure conditions over its entire system all of the time, but it is possible that such a condition could

exist, so that the full allowance of 18 per cent is seldom if ever given. An analysis of the company's records and of the inspector's tests will give a good idea of the extent of poor-pressure conditions, and penalties are imposed in proportion to the extent and of the importance of the business affected. With most of the rules, however, it is quite possible for the utility to fully meet the requirements and receive full credit.

I will attempt to follow through the rules giving an explanation of the reasons for the grades given.

CREEPING METERS (4 PER CENT)

RULE 14. *Electric.*—No electricity meter which registers upon "no load" shall be placed in service or allowed to remain in service.

If the records show and from other evidence it is found that the meters are over compensated on light load, in many instances, zero will be given on this rule; that is, the inspector will determine whether the full credit will be given or not.

ACCURACY OF METERS AS FOUND ON TEST (7 PER CENT)

RULE 15. *Electric.*—No electricity meter shall be placed in service, or allowed to remain in service, which has an incorrect register constant, test constant, gear ratio, or dial train, or which has an error in measurement in excess of 4 per cent between one-tenth and full connected load.

RULE 1. *Gas.*—No gas-service meter shall be placed in service, or allowed to remain in service, which has an incorrect gear ratio or an error in measurement in excess of 2 per cent when passing gas at the standard test rate of flow.

This rule covers the general meter accuracy, and compliance depends on the percentage of meters found within allowable limits of accuracy on test and whether or not the utility is prepared, with competent and properly instructed employees, to give and does give the best care to the meters.

INSTALLATION TESTS (5 PER CENT)

RULE 16. *Electric.*—Each watt-hour meter shall be checked for correct connection, mechanical conditions, suitable location, and accuracy of measurement at approximately three-quarters and one-tenth connected load by comparing the meter with approved suitable standards in its permanent position in place of service within 30 days after installation. Meters operating at low-power factor shall also be tested at approximately the minimum power factor under which they will be required to operate. Meters installed with instrument transformers or shunts must be tested jointly with the transformers or shunts, otherwise the ratio of transformation of the transformers or calibration of the shunts must be determined at least once every five years.

This applies like rule 14 only to electric meters, and a grade is given depending on the number of installation tests made compared to the number of meters installed during the period.

PERIODIC TESTS (14 PER CENT)

RULE 17. *Electric.*—Each watt-hour meter shall be tested according to the following schedule, and adjusted whenever it is found to be in error more than 1 per cent, the tests both before and after adjustment being made at approximately three-quarters and one-tenth of the rated capacity of the meter. Meters operated at low-power factor shall also be tested at approximately the minimum power factor under which they will be re-

quired to operate. The tests shall be made by comparing the meter, while connected in its permanent position, on the consumer's premises with approved suitable standards, making at least two test runs at each load, of at least 30 seconds each, which agree within 1 per cent.

Single-phase, induction-type meters having current capacities not exceeding 50 amperes shall be tested at least once every 24 months, and as much oftener as the results obtained shall warrant.

All single-phase induction-type meters having current capacities exceeding 50 amperes, and all polyphase and commutator-type meters having voltage ratings not exceeding 250 volts, and current capacities not exceeding 50 amperes, shall be tested at least once every 12 months.

All other watt-hour meters shall be tested at least once every six months.

In no case shall commutator-type meters having heavy moving elements and sapphire jewels be allowed to make more than 1,000,000 revolutions between tests. Where meters are found to register considerably in error when tested on the above schedule, the commission reserves the right to order the particular meter or class of meters tested more frequently.

RULE 2. *Gas.*—Each gas-service meter shall be tested before installation, and shall be removed, tested, and overhauled at least once every 48 months, and adjusted whenever it is found to be incorrect. At least two consecutive test runs must be made which agree within one-half of 1 per cent.

(See Temporary order, p. 11, Standards of Gas and Electric Service.)

This rule is divided into companies' testing methods and the result, with 5 per cent for methods and 9 per cent for results. When the utility has a practice of keeping a large proportion of the meters tested in compliance with this rule the part of the 9 per cent to be allowed is determined by the proportion of the number of meters found tested compared to the total number connected. If testing practices are correct, the full 5 per cent is allowed or a proportionate amount if not, but if at recurring inspection a number of meters are found not tested, the total 5 per cent will be deducted.

METER-TEST RECORDS (5 PER CENT)

RULE 18. *Electric.* Whenever an electricity meter is tested the original test record shall be kept indicating the information necessary for identifying the meter, the reasons for making the test, the reading of the meter before being disturbed, a statement regarding creepage and the accuracy of measurement, together with all data taken at the time of the test. This record must be sufficiently complete to permit the convenient checking of the methods and the calculations. All utilities having more than 250 electricity meters in service shall maintain a meter record, numerically arranged, indicating approximately when the meter was purchased, its identification, its various places of installation, with dates of installation and removal, and the dates and general results of all tests, and shall tabulate the results of tests according to types of meters and intervals of test, compiled monthly and annually.

RULE 3. *Gas.*—Whenever a gas service meter is tested the original test record shall be kept, indicating the information necessary for identifying the meter, the reason for making the test, the reading of the meter before being disturbed, and the accuracy of measurement, together with all data taken at the time of the test. This record must be sufficiently complete to permit the convenient checking of the methods employed and the calculations. A record shall be kept, numerically arranged, indicating approximately when the meter was purchased, its size, its identification, its various places of installation, with dates of installation and removal, and the dates and general results of all tests.

A complete set of meter records which are kept up to date will give a full percentage of compliance, but incomplete records will reduce and no history cards will wipe out any credit

METER-TESTING EQUIPMENT AND METHODS (5 PER CENT)

RULE 19. *Electric.*—Each utility furnishing metered electric service shall own suitable working standards for the testing of electricity meters, and either maintain these standards correct within one-half of 1 per cent or apply the proper correction to all tests. Secondary standards of some approved type shall be owned and maintained by each utility having more than 250 electricity meters in service.

RULE 4. *Gas.*—Each utility furnishing metered gas service shall own a suitable meter prover, and maintain the same in proper adjustment to register the condition of the meters within one-half of 1 per cent. The meter prover shall be so placed as to be shielded from excessive temperature disturbances, and shall be equipped with suitable thermometers and other necessary accessories.

The meter-testing equipment of the utility must be complete and suitable or must be available and tests be properly made for full compliance which will be determined by the inspector after following through the methods of the company's employees. Deduction will be made where these conditions are not met.

REQUEST TESTS (4 PER CENT)

RULE 20. *Electric.*—Each utility furnishing metered electric service shall make a test of the accuracy of any electricity meter upon request of the consumer, provided the consumer does not request such test more frequently than once in six months. A report giving the results of each request test shall be made to the consumer, and the complete, original record kept on file in the office of the utility.

RULE 5. *Gas.*—Each utility furnishing metered gas service shall make a test of the accuracy of any gas service meter upon request of the consumer, provided the consumer does not request such test more frequently than once in six months. A report giving the results of each request test shall be made to the consumer, and the complete, original record kept on file in the office of the utility.

Compliance with this rule depends on whether these tests are made willingly and promptly, complete records kept, and the consumer promptly informed of the result. If evidence is found to the contrary deductions will be made.

REFEREE TESTS (0 PER CENT)

RULE 21. *Electric.*—Any electricity meter may be tested by an inspector employed by the commission upon written application of the consumer. For such test a fee shall be forwarded to the commission by the consumer when making application; the amount of this fee shall be refunded to the consumer by the utility if the meter is found to be fast beyond the 4 per cent limit. The amount of fee to be collected for these tests so made shall be $2 for each single phase or continuous current electricity meter having a voltage rating not exceeding 250 volts and a current capacity not exceeding 25 amperes without having instrument transformers; for other electricity meters having a capacity not exceeding 100 amperes the test fee shall be $4 per meter; for all others the fee shall be $8 per meter.

RULE 6. *Gas.*—Any gas service meter may be tested by an inspector employed by the commission upon written application of the consumers. For such test a fee shall be forwarded to the commission by the consumer when making application; the amount of this fee shall be refunded to the consumer by the utility if the meter is found to be fast beyond the 2 per cent limit. The amount of fee to be collected for tests so made shall be $2 for each gas service meter having a capacity not exceeding 10 lights; for other gas service meters having a capacity not exceeding 45 lights, the test fee shall be $4 per meter; for all other gas service meters the test fee shall be $8.

Since the utility has nothing to do with this rule, no weight is given.

METER READINGS ON BILLS (4 PER CENT)

RULE 22. *Electric.*—Bills rendered periodically for metered electric service shall designate the reading of the meter at the beginning and end of the interval for which the bill is rendered and shall give the dates of the reading of the meter.

RULE 7. *Gas.*—Bills rendered periodically for metered gas service shall designate the reading of the meter at the beginning and end of the interval for which the bill is rendered and shall give the dates of the reading of the meter.

If no meter readings are put on the bills, the whole amount is deducted and one-half when the readings are put on, but dates omitted.

HEATING VALUE (21 PER CENT)

RULE 8. *Gas.*—Each utility furnishing gas service must supply gas of such standard heating value as will enable it to obtain the greatest practicable efficiency with its equipment and the raw material available, giving due consideration to the uniformity of the quality of the service rendered. A minimum monthly average shall be maintained of not less than 520 British thermal units total heating value per cubic foot, as referred to standard conditions of temperature and pressure. No fluctuations from the standard selected by the individual companies shall exceed 4 per cent below, or 5 per cent above, that standard. The tests to determine the heating value of the gas shall be made anywhere within a 1-mile radius of the center of distribution.

If the company is equipped with a calorimeter: When the heat content of the gas as found by the inspector and as shown by the company's records is within 4 per cent below or 5 per cent above the standard of 520 B. t. u., or a standard above 520 B. t. u. adopted by the company, the full amount of credit is given. Deductions are made, depending on the number of days that the record shows the value to be outside the limits and on the amount of variation either above or below. If the company has no calorimeter: If the inspector's tests show the heat content of the gas to be within the above limits, full credit is given with deductions if it is found outside the requirements.

CALORIMETER EQUIPMENT (7 PER CENT)

RULE 9. *Gas.*—Each utility, whose gas output exceeds 20,000,000 cubic feet per year, shall equip itself with a complete standard calorimeter outfit, and shall determine the heat value of the gas on at least three days each week. A record of all of these tests shall be made and kept open for public inspection.

If utilities with outputs exceeding 20,000,000 cubic feet per year have not installed or are not using a calorimeter as required, no credit is given; utilities not required to have a calorimeter are given full credit.

INTERRUPTIONS (18 PER CENT)

RULE 23. *Electric.*—Each electric utility shall make all reasonable efforts to eliminate interruptions in service, and when such interruptions occur shall endeavor to reestablish service with the shortest possible delay. Whenever the service is interrupted for the purpose of working on lines or equipment, this shall be done at a time which will cause the least inconvenience to consumers, and those most seriously affected by such interruptions shall, if possible, be notified in advance.

Compliance with this rule is based upon the number of interruptions to service, the length, and whether they are reasonably avoidable or not. Some weight is also given to the class of consumers served and whether or not the interruptions affect the whole, a major portion, or only a small part of the system. Interruptions of the whole service are classed as few, short, unavoidable; few, long, unavoidable; few, short, avoidable; few, long, avoidable; many, short, unavoidable; many long, unavoidable; many, short, avoidable; and many, long, avoidable.

STATION RECORDS (6 PER CENT)

RULE 24. *Electric.*—Each utility furnishing electric service shall keep a record of the time of starting and shutting down power-station equipment and feeders, together with the indication of the principal switchboard instruments, at sufficiently frequent intervals to show the characteristics of the load; and shall maintain a record of all interruptions of service upon the entire system or major divisions of its system, and include in such record time, duration, and cause of each interruption.

A complete station log will be given full compliance, but if lacking a record of interruptions showing cause, duration, etc., only one-half to two-thirds credit will be given.

PRESSURE AND VOLTAGE VARIATION (18 PER CENT)

RULE 25. *Electric.*—Each electric utility operating in a city having a population of 1,500 or more shall adopt a standard voltage for the entire constant potential system, and shall maintain the voltage within 3 per cent of such standard on all lighting circuits during lighting hours; on power circuits and during other than lighting hours the voltage shall be maintained within 10 per cent of the standard. All other electric utilities shall maintain their voltage regulation on constant potential circuits during lighting hours so that the maximum voltage furnished any consumer shall not be more than 6 per cent above the minimum voltage at that consumer's cut-out.

RULE 10. *Gas.*—Gas pressure, as measured at the outlet of the company's service to any consumer, shall never be less than 2 inches nor more than 6 inches of water pressure, and the maximum pressure at any such outlet on the system shall never be greater than double the minimum pressure at that outlet.

A large percentage, about 15 per cent, is given if the pressure requirements are met with electric service during lighting hours and 3 per cent for balance of the 24 hours. With utilities not giving service except during lighting hours, compliance is figured on the whole 18 per cent. Deductions are made, depending on amount of variation from the standard voltage and for variations below the standard on parts of the system.

With gas service full compliance is allowed when the inspector is convinced from the company's records and tests made at the time of the inspection that the requirements of this rule have been met for the period which the inspection covers. Deduction for violation of this rule will depend on the number of consumers affected, although not in proportion since the variation in gas pressure and particularly low pressure vitally affects the service. In the absence of suitable records made by the company the inspector must judge the degree of compliance by the tests made by himself and by taking into consideration the holder pressure, length and size of mains, amount of consumption, the elevations, and by a study of the complaint records.

PRESSURE AND VOLTAGE SURVEYS (6 PER CENT)

RULE 26. *Electric.*—Each utility furnishing electric service shall provide itself with one or more portable indicating voltmeters, and each utility serving more than 250 consumers shall have one or more portable graphic recording voltmeters, these instruments to be of a type and capacity suited to the voltage supplied. Each of the utilities shall make a sufficient number of voltage surveys to indicate the service furnished from each transformer and feeder and to satisfy the commission of its compliance with the voltage requirements, and those having graphic recording voltmeters shall keep at least one of these voltmeters in continuous service at the plant, office, or some consumer's premises. All voltage records are to be kept for public inspection.

RULE 11. *Gas.*—Each gas utility shall provide itself with one or more portable graphic recording pressure gauges, and shall make frequent measurements of the gas pressure and pressure variation throughout the system, and these shall be kept on record and open for public inspection.

The compliance with this rule depends on whether or not the utility is fully equipped with recording gauges and the judgment used in making the surveys, as to the proper time and the location of the gauges, etc., and whether or not a complete and available record is kept for inspection. Deductions will be made, depending on the amount that the inspector feels that the surveys are incomplete.

PURITY (4 PER CENT)

RULE 12. *Gas.*—In no case shall the gas contain more than 30 grains of total sulphur per 100 cubic feet, and not more than a trace of sulphur as sulphuretted hydrogen.

Complete tests for sulphur are impracticable and compliance with this rule, therefore, depends on the hydrogen sulphide tests. A deduction of 2 per cent, one-half the weight of the rule, is made if the utility does not make and keep a record of such tests; if only an occasional test is made a deduction of 1 per cent is made, and if the test made by inspector shows a trace of H_2S a deduction of 1 per cent is made and if strong evidence is found, deduct 2 per cent.

COMPLAINT RECORDS (5 PER CENT)

RULE 13. *Gas.*—Each company shall keep a record of all complaints made, which shall include the name and address of the consumer, the date, the nature of the complaint, the remedy, and date of completing the work. This record shall be kept open for public inspection.

No record at all will mean zero on this rule. From an inspection of the complaint records a determination is made of the degree that the requirements of this rule are met as to completeness of the record.

INFORMATION (4 PER CENT)

RULE 27. *Electric.*—Each utility supplying electric service shall specifically inform each of its consumers as to the conditions under which efficient service may be secured from its system and render its consumers reasonable assistance in securing incandescent lamps and other appliances best adapted to the service furnished.

A utility is required by this rule to properly advise the consumers regarding the proper lamps and motors to use, etc., and, in fact, to show a proper attitude to the public. The degree of compliance must be determined from observation by the inspector.

TELEPHONE UTILITY GRADING

In the grading of utilities giving telephone service, according to the degree of compliance with the commission's rules for service, very careful consideration was first given to determine what should be the proper weight to be given to each rule.

The rules relating to the construction and maintenance of equipment and lines, rule 1, and relating to speed, accuracy, and supervision of service, rule 7, were given equal weight of 15 per cent.

The rule covering the exchange equipment (switchboard capacity, etc.), operating force, and traffic studies, rule 5, was considered next in importance and given a weight of 12 per cent.

Next in importance comes the continuity of service, elimination of irregularities, and promptness of taking care of trouble, rule 11. In this is included the trouble record. This rule is weighted 11 per cent.

Rule 4, which is considered as next of importance, refers to tests and inspections to assure continuance of proper service. This rule merges somewhat into rule 1 on maintenance and rule 11 on continuity of service. This rule is weighted 10 per cent.

The rule relating to and limiting the number of subscribers on a line to a number not greater than or consistent with good service is given a weight of 8 per cent.

The rest of the rules are considered of about equal importance and are given a weight of 4 to 6 per cent.

In determining the percentage of compliance on the different rules the following practice has been followed by the inspector:

EQUIPMENT AND MAINTENANCE (15 PER CENT)

RULE 1.—Equipment and lines shall be so constructed and maintained as to eliminate all cross talk and noise which unreasonably interfere with the transmission of messages for ordinary distances.

A reduction of 4 per cent is made for cross talk and 4 per cent for bad noise on the lines. The remaining 7 per cent covers adequacy of distribution equipment and maintenance of the same.

LOADED CIRCUITS (8 PER CENT)

RULE 2.—The number of subscribers on any one line shall not be greater than that consistent with adequate service.

In general, the number of subscribers on a rural line must be determined by the requirements of the people served and may be limited to 10 or 12, but because of the nature of the territory or the limited means of the subscribers in the territory as a class, the number may be increased materially. A subscriber should have available to him as high a grade of service as the utility can furnish, providing, of course, he is willing to pay a compensatory price for the service. No subdivisions are made under this rule and the inspector grades according to his best judgment.

THROUGH LINES (5 PER CENT)

RULE 3.—Each utility, furnishing service alone or jointly with other utilities in two or more cities, villages, or other exchange points shall provide at least one line for through traffic between such points, along which few, if any, subscribers' instruments are installed.

A utility is expected to provide enough circuits interconnecting the communities being served to properly take care of the traffic, and

only where there is very little business between these communities will subscribers' connections be allowed to these lines. Compliance is determined by the adequacy of these through-line facilities.

TEST AND INSPECTIONS (10 PER CENT)

RULE 4.—Each utility shall maintain in proper condition the lines, instruments, and other equipment used on its system and shall make such tests and inspections as are necessary.

This rule does not specify what tests shall be made nor just what inspections are necessary, but because these are required, a utility which has no regular plan of making such tests and inspections or, if they are made, can show no results recorded will have deducted at least 3 of the 10 per cent. The actual condition of the whole system will determine the amount of the remaining 7 per cent which will be allowed.

ADEQUACY OF EQUIPMENT (12 PER CENT)

RULE 5.—Each exchange shall have sufficient switchboard capacity, and a sufficient operating force to handle the traffic at all times with reasonable facility. Traffic studies shall be made and recorded of such extent and frequency as to demonstrate to the commission that sufficient equipment is in use and that an adequate operating force is employed.

Central office equipment proper for the traffic is given 3 per cent; sufficient operating force 3 per cent; night service 2 per cent; Sunday and holiday service 1 per cent; traffic studies, if necessary in the discretion of the inspector, 3 per cent. There should be no time when it is impossible to get a call through if it is necessary, and so a utility is penalized that does not in some way provide such service.

A careful study of traffic conditions is necessary to any well conducted, medium sized exchange, so this is given as much weight as anything else under this rule.

EMERGENCY PROVISIONS (6 PER CENT)

RULE 6.—Reasonable provision shall be made against the failure of lighting or power service, fires, and storms, sudden increases in traffic, the illness of operators, or other emergencies which would seriously impair the service if not promptly met.

Proper provision for emergency operators will count 2 per cent; for substitute means of ringing, headsets, and for fire protection, etc., 2 per cent; and for a proper supply of materials which may be needed on short notice, 2 per cent.

SPEED AND ADEQUACY OF SERVICE (15 PER CENT)

RULE 7.—At exchanges serving 500 or more subscribers 94 per cent of the calls should be answered within 10 seconds or less. At all other regular exchanges 90 per cent of the calls should be answered within 10 seconds or less. At small exchanges, operated in connection with other work, slower service may be adequate. Calls shall be carefully supervised and parties disconnected promptly after conversations are completed.

For the larger exchanges the utility is expected to make and keep a record of test calls. The inspector will make such calls and from these records the speed of the operators is determined as well as the

supervision and promptness of disconnection. The utility is then graded on a basis of speed of answer 8 per cent, supervision 4 per cent, and prompt disconnection 3 per cent.

In the smaller exchanges the same speed is not expected where the operating is done in connection with other work, but the inspector should determine when the traffic is sufficient to require an operator on the board continuously.

OPERATORS' SERVICE RULES (4 PER CENT)

RULE 8.—Suitable rules and instructions shall be adopted covering the phraseology and methods to be employed by operators in handling regular and special calls.

This rule is important, that the operator may know just what is required of her and that at all times there may be assured to the subscribers speed and adequacy of service, courtesy, absolute secrecy, security from business diversion, etc. Compliance with this rule depends upon having the rules and enforcing them.

DIRECTORIES (5 PER CENT)

RULE 9.—Directories in which 1,500 or more subscribers are listed shall be revised at least semiannually. All other directories shall be revised at least once each year. All directories shall be dated.

Compliance with this rule, of course, depends on the issuance of the directory as required.

RULES AND INSTRUCTIONS (5 PER CENT)

RULE 10.—Directories shall contain such instructions and rules governing local and toll service and methods of payment as may be necessary to inform subscribers of their rights and obligations.

All rules for the instruction of the public should be included, as well as toll and local rules, for full compliance. Regulatory rules might well be included.

REGULARITY OF SERVICE AND TROUBLE RECORDS (11 PER CENT)

RULE 11.—Reasonable efforts shall be made to eliminate interruptions and irregularities, and to correct them promptly when they occur. Records shall be kept of all complaints or irregularities in the service, showing the day and time at which the trouble is reported, the nature of the trouble, its duration, and final disposition.

In many instances recurring failure of telephone service, from any particular cause, properly investigated, will lead to the permanent removal of the cause if right methods are followed. It is for this reason that many companies keep a detailed record of trouble reports and by analysis are enabled to do away with parts of the equipment which are the source of interruptions to service. The infrequency of interruptions and the completeness of trouble records, together with the promptness of caring for trouble will determine compliance with this rule.

INFORMATION TO COMMISSION (4 PER CENT)

RULE 12.—The name and address of the official or employee designated to handle service matters, and a copy of each new directory shall be filed with the commission. Upon request a complete map of each telephone system shall be filed with the commission, and a similar map shall be kept at the principal office of each utility and revised from time to time as changes in the system are made.

It is necessary to know who is responsible for the service of a particular company, and the regulatory body should have this information as well as the knowledge of the extent of the company's system.

For the last few years the service requirements imposed by the Wisconsin Railroad Commission have been tempered materially because of the difficulties which have been the lot of all public utilities, and doubtless this condition has been prevalent throughout the country.

Special cases which have arisen because of conditions resulting from the war have engrossed largely the time of our engineers so that the personnel of the staff was not sufficient to handle the service matters thoroughly and do the extra special work.

For these reasons the work of grading the utilities has not been complete; that is, while grades have been given with the reports on all inspections, it has not been possible to make the inspections of all the localities and, therefore, comparative summaries have not been made for two or three years.

We are getting caught up again, though, and will have our summary of the gas companies again for this year for inspection by the utility representatives at the gas and electric association convention this month.

The results of grading of telephone utilities have never been summarized and submitted to the companies for the reason which, I believe, can be stated at this conference with propriety, namely, the very obvious difference between the general service conditions found in Bell exchanges and those existing in the average independent exchange.

Our grading shows that the poorest exchange of the Bell interests will seldom fall below 90 per cent and the average about 92 to 93 per cent, while the marking of the independents will vary from 30 to 97 per cent. I do not want you to infer that we believe the independent exchange is not making the effort to improve the service, for, in fact, the contrary is true.

The Bell exchanges are, in most instances, in the larger localities, and the managers working under a definite and well-seasoned policy are enabled to bring about the best results from a service standpoint, and the independent exchanges in the larger towns are well up to the standard service. The rank and file of independent exchanges, however, are in the smaller centers hampered, if I may use the term, with a large number of switched roadway companies with whom good service has in the past not been considered of the greatest importance.

I want to say, though, that we have in our State some of the most progressive independent operators, who are doing wonderful missionary work among the smaller operators through the State independent telephone association, and this work has resulted in the

smaller operator coming to see the necessity for better service conditions.

It is quite possible that within a short time we will decide to make public our telephone utility grades, because of this marked improvement in the service.

It is our opinion that the practice of grading has been of great value as an aid to the department and has been generally looked upon favorably by the utilities.

Since Mr. Mathews, of Illinois, was unable to attend the conference, the following paper prepared by him was read by Dr. J. Franklin Meyer:

GRADING OF PUBLIC UTILITY SERVICE

By J. Howard Mathews, *Service Engineer, Illinois Commerce Commission*

In thinking of service of public utilities, we are likely to have in mind only a few of the most important factors. When the average user of electric service says service is poor, he usually means it is subject to frequent interruptions, or possibly, the voltage is low. The gas consumer makes complaint if he has difficulty in cooking or if he is unable to get any gas. These are no doubt some of the most important matters to be considered in classifying electric and gas service, but an analysis of the records of any utility or of any regulatory body will show almost every conceivable objection to the service. Criticisms are made of the equipment, methods of operation, kind of treatment accorded consumers, extension policies, accuracy of meters, and many other features. The Illinois Commerce Commission law defines service as including not only the use or accommodation afforded consumers or patrons but also any product or commodity furnished by any public utility and the plant equipment, apparatus, appliances, property, and facilities employed by the utility in performing its service. This definition has been found none too broad to cover the large range of subjects to which attention must be directed if patrons of public utilities are to be satisfied. In this broad sense, we are really considering the treatment accorded the consumers, and every factor that enters into treatment may properly be termed a factor of the service.

In every move a utility makes, in everything it does, there is a service done or omitted. From the time the prospective electric consumer first interviews a utility representative about securing service until his service is discontinued and final bill paid, the utility's sole business is to serve him. For his electric energy and gas he pays directly on a metered basis as does his neighbor, but he is entitled also to continuous service, good voltage, gas of good pressure and quality, information courteously given, and to careful consideration of complaints for which he pays only indirectly.

More specifically, the most important factors that enter into the furnishing of gas and electric service and which are given consideration in our grading system are listed below:

Electric Utilities:

1. Continuity of service.
2. Voltage regulation.
3. Handling of complaints.
4. Accuracy of meter registration.

ELECTRIC UTILITIES—Continued
5. Construction and maintenance.
6. Adequacy of capacity.
7. Provisions for emergency.
8. Adjustment of bills.
9. Billing.
10. Extension policy.
11. Promptness in furnishing new service.
12. Courtesy of utility representatives.
13. Testing of service and keeping of records.

GAS UTILITIES:
1. Pressure (including continuity).
2. Heating value.
3. Handling of complaints.
4. Purity.
5. Adjustment of appliances.
6. Construction and maintenance.
7. Adequacy of capacity.
8. Provisions for emergency.
9. Adjustment of bills.
10. Billing.
11. Extension policy.
12. Promptness in furnishing new service.
13. Courtesy of utility representatives.
14. Testing of service and keeping of records.

NEED FOR SERVICE RATING

In connection with our extensive study of service matters throughout the State, we have become impressed with the need for some system of comparing gas and electric service in various communities. The necessity for such development arose out of the fact that it was practically impossible to state specifically how the service of one utility or in one town compared with that of another utility. In one town the continuity of electric service may be good and voltage regulation poor. In the other the voltage regulation may be good, but interruptions more serious than in the other community. In many respects the service in one might be better than in the other, while in other respects the service in the second may be better than in the first. In the absence of some form of abstract grading we were unable to answer intelligently an inquiry whether originating in our own minds or on the part of others as to the relative standing of two utilities from a service point of view. We could also see need for some brief yet concrete way of indicating service conditions in any community. We wanted something that would give the same information as a lengthy report. It was, therefore, found necessary to develop a method that would give some means of grading the service.

It was found advisable also to develop some scheme which could give more accurate information than a mere statement that a rule had been violated or complied with. If a few meter tests, for instance, are overdue the rule is, technically speaking, violated and must be reported as such by the inspector. A large number of rules, however, might be reported violated when the service was truly good. The number of rules violated does not necessarily fairly indicate the character of service rendered. The question with which we are most concerned is the importance of the rule violated, and the extent to which it is violated. Unsatisfactory gas pressure consti-

tutes a violation of one rule as does a failure to enter properly information taken in connection with the meter test. Obviously, the importance of the first far outweighs the other. Actual conditions of service are manifestly more important than are the records indicating the conditions of service, and yet the violation of a rule may appear in either.

METHOD OF GRADING

The plan as developed and shown hereinafter in detail shows at a glance the degree of perfection attained in each phase of service. This is done by giving a specific grade on the basis of 100 per cent for each factor. To take care of the relatively greater importance of one over the other, the grade as assigned by the engineer is multiplied by a fixed weight, the value of which depends on the importance of the factor. For instance, a constant of 30 is used where continuity of electric service is graded, whereas 1 has been chosen for use where information on bills is concerned. The total of the weights is 100. The various grades are multiplied by the respective constants, the products added and the final results so obtained divided by 100 to give the final grade of service. This final grade then takes into consideration the grade and relative importance of each of about 18 factors. The form used in grading is printed on the back of the service-inspection sheet, and the grades are assigned by the engineer making the investigation. They are checked against the report by someone other than the engineer making the investigation.

From the point of view of this office the plan provides a concrete, brief method of showing by a few figures what an engineer could not show in a voluminous report. It shows at a glance what particular features of service are satisfactory, and the extent to which others are unsatisfactory. It has a further advantage that it makes it necessary that an inspector make a very careful investigation of every feature of the service in order that he may grade it. The grading of any property tells a complete and interesting story.

The greatest advantage that we have seen, however, with the grading system is that it has had the effect of instilling into utilities and their representatives a spirit of competition in the matter of rendering satisfactory service to the public. Under the operation of this grading plan different utilities compete with each other. Different divisions of the same utility and different communities of the same division endeavor to stand higher than their neighboring division or community. The system has impressed upon utilities the importance of such factors as properly handling complaints and creating good public relations, which were not given so much thought before. It served to make a concrete and tangible objective out of the problem of "selling the company" to the community it serves, whereas this had previously seemed to so many employees as something of little practical importance.

Recently one of our larger utilities in a period of emergency desired service from another large utility. The latter was reluctant to furnish the service until it was assured by this department that should its voltage be affected for a few days due to the abnormal demand, we would overlook the voltage regulation for this period in

grading the service. I cite this instance to give an idea of the seriousness with which many of the public utilities view our grading system.

When we write a company about the results of an inspection we usually send a list showing the detailed grades given for each factor of service. Some of the organizations delegate individuals to visit this office in order that they may go over in detail the grades assigned and learn wherein they may improve their standing, which means incidentally, of course, that they must improve the service. Some of them make an immediate study of their distribution systems and operating conditions to see how they may improve voltage regulation or reduce interruptions, and the local manager is usually furnished with the details of the grade in order that he may improve service conditions in his locality, put his records in good condition, etc. We have been asked in a number of cases to make additional inspections a little later in order that the company's showing might be better.

On August 10, 1922, we mailed to all gas and electric utilities in the State a list showing the grades for gas and electric service in some 700 localities. The highest grade given was 96.45 and the lowest 56.50. Needless to say this occasioned considerable interest and we were very glad to find that the reaction was favorable indeed. Upon receipt of the list of grades, most of the utilities requested more detailed information, asking for the specific grade for each factor of service in order that they might concentrate their efforts on those particular features of service in which they had been found deficient. We have had practically not a word of criticism, nor has there been found any tendency to "whine" or find fault because some one did not receive as good a grade as some one else. There seemed to be a slight feeling at first on the part of one utility that there was too much guesswork about it, but when that organization became familiar with our detailed instructions it became one of the best supporters for the system.

Detailed instructions to inspectors have been prepared to insure uniformity of opinion and, so far as possible, to eliminate the element of personal judgment. These instructions are now so specific that by their use anyone would arrive at practically the same final grade as would one of our engineers. It has been our plan, which is apparent from a study of these instructions, to base the grading on service conditions and on records that any well managed company would desire to keep, rather than on compliance with the commission's rules. For this reason the operating companies can make use of these instructions to grade their own service, delegating some individual to study service conditions and to assign a grade on the basis of his knowledge as secured through inspections. Some of the most progressive utilities already have this under consideration and a general adoption of the plan would, we believe, be highly beneficial.

In order that all towns may have as nearly as possible an equal opportunity to stand at the head of the list, we are arranging to classify the electric and gas properties into four classes, A, B, C, and D. In classifying these properties we take into consideration a large number of factors, such as number of consumers, reasonably expected operating and financial ability (usually dependent on the size of the operating utility), whether served from a transmission line, con-

sumption per consumer, character of community, etc. Whereas it would be discouraging for small isolated properties to attempt to compete with large properties, they may be able to stand at the top of the particular class into which they fall.

One important use which we make of the grading is to use the grade assigned in determining the frequency of inspection, it being our theory that the towns which grade lowest should be given the most frequent inspections. Our periods vary from 6 to 18 months, depending upon the character of service rendered as reflected in the grade.

Detailed instructions to inspectors for arriving at values to be assigned to the various factors of gas and electric service are attached. (The instructions for rating electric service, with detailed tables showing the weights assigned to various elements of service and the deductions to be made for specific deficiencies, have been published by Mr. Mathews in the Electrical World, volume 81, pages 1034–1036, May 5, 1923. Similar instructions are used for gas service.)

SECOND SESSION (AFTERNOON OF FRIDAY, MARCH 2, 1923)

DISCUSSION OF PAPERS ON GRADING OF UTILITIES

Doctor Wolff. The States of Wisconsin and Illinois are to be congratulated on the steps they have taken, first, in making a preliminary attempt to fix standards for telephone service, the most difficult group of standards to fix, and, second, in this next step of grading utilities. The importance of the steps taken comes from the fact that it marks the beginning of a realization that that which the public pays for, in the way of telephone service, has to be graded and that the companies furnishing such service also have to be graded. We must, however, make a careful distinction between the grading of service and the grading of the utilities rendering the service. The ratings in the two cases need not be the same, and apparently from the presentation of the two papers this morning, they are not always the same. Irrespective of any economic aspects of the question you can set a standard for service and you can grade a utility with respect to compliance with that standard in a perfectly rigorous way. However, there is a point that is entirely left out of account, possibly intentionally so at this time. The standard which should be set, the attainment of which is credited with a mark of 100, is the standard which best fits the needs of the public.

Take, for example, the matter of the time required to effect a local telephone connection, the time that elapses between taking the receiver off the hook until you get the party called. In the case of the type of switching equipment that is now being introduced in large multi-office areas, the time that elapses between lifting the receiver off the hook to the time when you get the ring back is a matter of some 20 to 25 seconds. Apparently an entirely different value is now being placed on speed elements of telephone service than in the past. The point I am trying to emphasize is that the public may have been educated to a point where it insists upon an exceedingly prompt answer and that this promptness may not be in balance with the time required to get the party called. Moreover, in this city, for example, we have a residence measured-service rate with 50 calls per month, or 600 calls per year, and it is well known that the average residence subscriber does not go very much beyond the minimum number of calls. Suppose that the answering time in this case was 5 seconds, 50 minutes in the aggregate in a whole year. On the other hand, what is the value of the time of the average person who uses the telephone? Of course, if he wants a doctor in a hurry, lost seconds may mean lost lives, but the average residence subscriber has no real need for an immediate answer by the operator. If the subscriber were paid for his waiting at the rate of $1,200 per annum on a seven-hour day basis, that would aggregate 50 cents a year. But how much increased efficiency is required, how much more cost is

involved to enable the telephone company to render three and one-half seconds service as compared with five seconds service? This is a question which will have to be considered in grading utilities and grading service. The one big factor, therefore, which has not been adequately stressed is that the method of grading which has been proposed by Wisconsin and Illinois enables the company that is willing to spend a sufficient amount of money to render service of any quality which it may set, without reference to whether the value of the service is thereby correspondingly enhanced. Eventually the rating of utility service (we may not be ready for it now by any means) must take into account the relation between the quality of service rendered and the cost of rendering that service.

Mr. HAYDEN. I wish to say that in our grading of the telephone companies it has not been the thought to carry it to the extreme, the idea being that reasonable service is considered as meeting the requirements of the standards of service. As far as the speed of answer is concerned, we have put as a basis that 90 per cent of the calls should be answered within 10 seconds. You can see that we are not getting into refinements of the question at present at least, and we have not had any particular intention of emphasizing the speed of answer.

Doctor WOLFF. Take the matter of continuity of service, there can be such a thing as supermaintenance involving unjustifiable maintenance costs. Perfect continuity of service would involve prohibitive cost. Each of the elements of service must eventually be viewed from that angle, to the end of attaining an economically balanced whole.

Mr. COVELL. The Wisconsin method rates companies on the quality of service rendered. The Illinois method takes into account the maintenance and method of operation of the plant. Of course, if a plant is poorly maintained, that poor maintenance will eventually affect the service, but there is this question in my mind: Is it not desirable to consider the condition of the plant as well as the quality of the service? A poorly maintained plant may be giving just as good service as another plant which is maintained well. At the same time the poor maintenance causes an increase in operating expenses and also will eventually affect the service. I would like to hear Mr. Hayden's ideas on the subject.

Mr. HAYDEN. In regard to maintenance, that is an important factor in determining the standing of a telephone utility, because the maintenance is immediately reflected in the service which the telephone company gives. Inasmuch as the rules do not require maintenance, except in so far as it may be included in the general public policy that I spoke of at the start, we have not entered it into the grading with the thought that it would ultimately be reflected in the service.

A MEMBER. If so, is not that rather misleading?

Mr. HAYDEN. You know it is always said that the inspector should wear gum shoes and go around when nobody knows anything about it. With the telephone service it is absolutely necessary that the inspections be made when the manager and operator know nothing about it. The manager has to do the same thing that we have to do, and that is what any telephone manager who wants to find out anything about his own service has to do.

Mr. Toeppen. There are two points that I would like to bring out. First, an inspector or observer in a telephone company can not work in an office without the operators getting wise to his presence. Second, grading on occasional inspections alone is not enough, for the general run of service is more essential than anything else.

Mr. Snook. I'd like to ask Mr. Hayden if he has made a comparative study along the line of human relations to show how it lines up with the rest; that is, whether the opinions of the companies' customers coincide at all with the grading made by the commission. It seems to me that this point of human relations is one of the most important ones to the public utility. I am wondering if either one of these commissions who have tried out this system have ever considered the question at all or have looked to that particular item, and, if not, if they have made any tentative plans. I would like to know what they think about it.

Mr. Hayden. I will be very frank in saying that I do not believe you can gauge the value of the services rendered by the public opinion of it, because in my own observation there have been some utilities that have given very poor service and have a good reputation with the public because the operators knew how to put things before the people. I have seen utilities giving the finest kind of service lose favor simply because they did not know how to get across proper public relations.

Mr. Wolf. In the giving out of these grades, doesn't the commission in a sense act against the very thing they are trying to attain? There are instances where the utility might be giving the best service in the world and still not be able to get it across to the public. There are also cases where the service needs improvement, but the first thing necessary is support from the public to make betterments of service possible. In reporting low grades for such cases, do you not add to the difficulties of getting better service?

Mr. Hayden. We certainly are getting good results in the opinion of the commission by this means.

Doctor Wolff. It was indicated that the public utility is rather sensitive to anything affecting its pocketbook. Is it not also true that the public is very sensitive on that same score? May not dissatisfaction result from the rates they have to pay for that service? And that raises the question as to whether or not the service which is being rendered may not be of a quality higher than the people would demand, so that correlation between public relations and your grading may be in part explained by not taking into account in your grading what you get for a dollar.

Mr. Hayden. I would like to say that Doctor Wolff has gone just a little too far. We are making minimum standards, the idea being that these are minimum requirements. We have not made this matter of service grading so prominent that the utility must go to extremes in maintenance in order to get a good rating.

A Member. In a rate case does the grade assigned for the service enter into the rate of return?

Mr. Hayden. The grade that we have given the utility has an influence in establishing the rates for the utility. The question of the utility's service is referred to the service department and the commission may ask for a report on the service of the utility. In making up such a report we take into account the grading that utility has.

Mr. VANNEMAN. There is one thought that occurs to me besides the one Doctor Wolff has expressed. Taking Wisconsin, where regulatory power has been about as broad as any in the country, as an illustration the application of the grading system might be said to show up the work of your commission in a retroactive sense. I have noticed ratings as low as 50 per cent on the list of gas companies. If such a system prevailed New York State and such a result were broadcast, I am afraid that some of the localities would come back at the commission with the questions, "What have you been doing?" "Why have you permitted such poor service to be given?" For that reason I have some doubt as to the advisability of adopting the system.

Further, I do not think it is fair to parallel corporations. Certain corporations in New York State are capable of giving the very highest possible service, capable not because of any special means or efficiency, but because of the number of consumers in a given area; while there are other companies giving poorer service, but nevertheless the very best service possible under the conditions existing, especially those cases where there are a limited number of consumers who naturally can not expect to get the same degree of service on a relative rate as is rendered in areas more favorably situated. Some have rates which the public will believe to be commensurate with the service given, while in other cases the public will contend that the rates are too high.

Mr. HAYDEN. In regard to the first question as to what explanation the commission has to make for allowing the company to operate with a standing as low as 50 per cent, I will say that our plan in carrying out the laws affecting utilities has always been to deal with the utility in the way that we felt would get the best results, namely, not to immediately start in and penalize the utility if they did not come across and do what they should do, but to work with them. This has been justified in our work with the telephone utilities particularly. If we had tried to enforce these telephone standards rigidly, opposition from the utilities would have been the result. We realized this and tried to use the same method that we have used in carrying out the rules for other lines of service, and the result has been very good. I think that everybody who is familiar with the Wisconsin situation feels that the improvement in the quality of telephone service in Wisconsin has been wonderful. Similarly with the gas companies. It does not help them to apply penalties if the public is not getting what it should get. If we were to apply some rigid method and take them before the attorney general we would not accomplish anything, but this grading of service exerts a continual pressure for improvements that will bring up the grade of the service.

Mr. BROWN. I have one thought to suggest as a telephone engineer. There is no question but that grade of service can be defined and measured, but there is great difference of opinion in regard to details of the matter. For example, you can not give the same grade of service with magneto equipment as you can on common battery equipment. It seems to me that a company serving a small community with magneto equipment would render a lower grade of service than with a common battery equipment. Yet that company should certainly be rated at 100 per cent if it gives the best service possible with equipment suited to the size of the community.

Mr. Hayden. We have telephone utilities which are simply what are known as roadway companies. Each utility, as far as its own service is concerned, can attain as high a rating as is possible, because, as I tried to state in my paper, a condition, such as the number of subscribers on a line, is determined by the locality served. I know of a place in Wisconsin where there are 30 parties on a line. The line runs up the valley of a river. These people have their own service for communication with each other. They can talk with each other just as much as they are a mind to, and have little or no use for outside connection.

Mr. Vanneman. One phase that struck me was that it seemed to me, from my recollection of Mr. Hayden's paper, that inspections were made at intervals varying up to 18 months apart, and then how does he compare the different companies with some others that have been inspected as often as once a month?

Mr. Hayden. We apply it just as Secretary Hoover says. We apply weighting. We consider the number of inspections made and the time which elapses. In addition, we limit inspections on an electric utility that stands 85 per cent or above. We would not make an inspection there perhaps in a year or year and a half. Somewhere else where the rating is low we make more frequent inspections. We try to bring up the service by making more frequent inspections where they are necessary.

Mr. Crittenden. The next paper is on the problem of inductive interference. This problem, as you all know, is an exceedingly intricate and difficult one, on which the bureau has done no specific work. In listing the problem here, the purpose has been simply to raise the question of how best to go about meeting it. It is with this idea in mind that Mr. McCollum has prepared his paper on the subject.

GENERAL REVIEW OF THE INDUCTIVE INTERFERENCE PROBLEM

By Burton McCollum, *Electrical Engineer*

INTRODUCTION

During the last few years there has been pressed upon the attention of power and signal companies and public utility commissions a problem of far-reaching importance, resulting from inductive effects on communication circuits caused by power circuits operating in close proximity to them. This problem is one presenting considerable difficulty for utility commissions, partly because of the complexity of the technical factors involved and partly because the problem is a relatively new one and there are few precedents to serve as a guide even in dealing with the broader phases of the problem and none at all relating to many important aspects of it. The problem is rendered more difficult because its solution involves not technical factors alone, but presents import economic and legal aspects which are inseparable from any comprehensive treatment of the subject. In the present paper no attempt is made to enter into any detailed discussion of the many technical factors involved in the problem. An attempt will be made, however, to review briefly the more important physical principles on which inductive interference

rests and the chief technical factors involved in the mitigation of the troubles. A brief résumé will then be given of the more important principles that must be considered in any comprehensive treatment of this question, a review of the progress that has been made by State commissions in dealing with it, and of measures that are now being taken by the utility companies concerned in an attempt to secure an adequate solution of this troublesome problem.

ELEMENTARY PRINCIPLES

The space around any conductor carrying an electric current is, in general, filled with two distinct types of fields of force, one of which is the electromagnetic field, proportional to the current in the wire, and the other is the electrostatic field, proportional to the voltage impressed upon the wire. The electromagnetic field is most logically regarded as comprising lines of magnetic force surrounding the wire in the form of closed circles or loops, while the electrostatic field can best be regarded as lines of electric stress extending radially in all directions from the wire. It is a well-known fact that if another electrical conductor or a group of such conductors are brought into close proximity to a wire carrying a varying electric current, voltages and corresponding currents will be induced in these neighboring wires. These induced currents are, in general, quite feeble in comparison with the currents in the power circuit giving rise to them, but in the case of telegraph and telephone circuits, the instruments connected to which are usually of extreme delicacy and sensitivity, interference of a substantial character may result in the functioning of the signal systems. It is this phenomenon that is referred to as inductive interference. Interference of a material character may result from either induction from the electromagnetic field or induction from the electrostatic field, and either may be the predominating factor in a particular case. As a general rule, however, under most practical conditions the troubles arising from electrostatic induction are more serious and more difficult to eliminate or control than those arising from electromagnetic induction. This is due chiefly to the fact that in most power transmission circuits the voltages involved are relatively high and the current for a given amount of power transmitted correspondingly small. There is also the further fact that the technical difficulties of eliminating the effects of electrostatic induction are usually more serious than those involved in controlling electromagnetic induction.

GENERAL EFFECTS OF INDUCTIVE INTERFERENCE

The consequences of these inductive effects on communication circuits are varied in character, depending upon conditions and on the uses to which such circuits are put. In the case of telephone circuits, the most common and serious difficulty is the production of noise in telephone instruments which may be of sufficient magnitude to reduce materially the usefulness of the service. In the case of telegraph lines the interference manifests itself largely through the operation of relays and the consequent obscuring of signals. If the inductive effects should become especially severe protective devices on the lines may be caused to operate, thereby putting the lines tem-

porarily out of commission. False ringing of telephone bells is also not an uncommon result of severe electromagnetic induction. In extreme cases also a distinct fire hazard has been alleged due to the blowing of fuses or a breakdown of insulation and other causes. Another trouble from this source which has recently begun to assume considerable proportions is the interference with radio reception due to certain types of induction interference. Because of the tremendous growth of the radio industry during the last few years and the still greater prospects for its growth in the future, it is not unlikely that this phase of interference may assume considerable importance.

Still another manifestation of inductive interference which, in comparatively few cases, has assumed serious proportions has to do with the personal hazard to operators of signal equipment, more particularly of telephone equipment. In extreme cases, due to short circuits or very sudden or extreme changes of load in power systems, currents may be induced in adjacent telephone systems sufficient to actuate the receivers of telephone operators with sufficient intensity to produce serious acoustic shocks. Numerous cases are reported in which the hearing of operators has been jeopardized by such acoustic shocks, and with accompanying temporary demoralization of the operating force. Also some cases have been reported of severe electrical shocks to operators due to very high voltage induced in telephone circuits resulting from severe transients in neighboring power lines. While accidents of this latter class are admittedly rare, they emphasize the extreme severity which may at times be attained by the effects of inductive interference.

TECHNICAL FACTORS UNDERLYING CAUSES OF INDUCTIVE INTERFERENCE

In considering the factors involved in inductive interference it is necessary to consider the general character of the currents existing in commercial power circuits. For the most part such currents comprise alternating current of relatively low frequency, in this country usually 25 or 60 cycles per second. These currents are the useful currents in the power circuits and are responsible for the conveyance of practically all the useful power which they transmit. These currents of fundamental frequencies induce currents of corresponding frequency in neighboring signal lines, but the effects of these low frequency induced currents in telephone systems are in most cases of relatively little consequence because the frequency is so low that they are comparatively inaudible. In the case of telegraph circuits, however, it so happens that the frequency of the instruments used is of the same order as these fundamental frequencies, and it is chiefly from induced currents from these low frequencies that interference from telegraph circuits results. In addition to these fundamental frequencies, there exist in practically all commercial power circuits harmonics of relatively high frequencies, which frequencies may be any odd multiple of that of the fundamental wave. In general, these higher harmonics lie within the range of from a few hundred to several thousand cycles per second, and it is also within this range of frequencies that both the ear and telephone receiver exhibit maximum sensitivity. These higher harmonics, though usually of small amplitude as compared with the fundamental wave, nevertheless give

rise to most of the disturbing effects resulting from inductive interference in telephone systems. These harmonics may arise from imperfections in the generating or distribution equipment itself, and may, therefore, be factors of permanent and persistent influence. Frequently, however, such harmonics are of a transient character due to temporary causes originating in the power system.

Interference with radio receiving equipment, in general, involves a third type of current far higher in frequency than those which cause trouble in telephone circuits. It is a well-known fact that arc lamps, certain types of circuit breakers, and transient discharges over defective insulators act substantially as radio transmitting stations sending out trains of electric waves of frequencies comparable to those used in ordinary radio transmission. These may at times be severe enough to interfere materially with reception of radio signals in their vicinity.

From the foregoing it will appear that interference in telegraph systems is due primarily to currents of fundamental frequency, and therefore to the useful current necessarily involved in the transmission of power. In case of interference with both telephone and radio systems the interference is caused by frequencies of higher range which not only play no useful part in the normal functioning of power systems, but, on the contrary, are in many cases objectionable from the standpoint of power operation. This is a fortunate circumstance, because any measures that may be taken to suppress these higher harmonics are beneficial alike to the power as well as to the signal systems. The detection and suppression to as great a degree as possible of these higher harmonics of audible and radio frequencies must, therefore, be regarded as prerequisite to any adequate treatment of the inductive interference problem.

REMEDIAL MEASURES

(*a*) *Suppression of harmonics.*—Taking up now the various major lines of procedure that may be followed in the mitigation of inductive interference troubles, it will be evident that the most logical first step will be to inquire as to what extent it may be possible to suppress or minimize the high frequency harmonics which, as has just been stated, are mainly responsible for the most serious interference effects. The suppression of these harmonics has long been regarded by the power companies as desirable because of certain objections to their presence in the system from the standpoint of operation. The existence of such harmonics in a power system may contribute appreciably to the heating of generators and transformers and may give rise to serious overstress on electrical insulations, resulting in interruptions or impairments of the service rendered by the power circuits. The high frequency harmonics, which are most concerned in producing inductive interference in telephone circuits, have their origin in imperfections in design of generators, improper design or operation of transformers, and other equipment connected to the power system. They may also be caused in transient form by switching operations incidental to the control or operation of the power circuit.

These higher harmonics are especially detrimental from the standpoint of inductive interference not alone because they are of fre-

quencies giving rise to much higher audibility than fundamental waves. There is a further fact that the problem of suppressing the inductive influence on neighboring lines is much more difficult than that of suppressing the inductive influence of the fundamental waves. In the case of fundamental waves it is comparatively easy to maintain a close approximation to a balance of the currents on the several wires of the transmission line, and in this way the algebraic sum of the currents of fundamental frequencies at any point in the transmission line may easily be kept very close to zero. This is not true, however, in the case of many of the higher harmonics. It is a fact well known to electrical engineers that in any three-phase system the third harmonic, as well as the odd multiples thereof, bears such a phase relation to the fundamental wave that at any given instant the harmonics in the three lines are flowing in the same direction. This results, in a case of an ungrounded line, in charging currents surging back and forth from one end of the line to the other. In the case of a three-phase line grounded at one end at the neutral of a star connected bank of the transformers, the charging currents flow between the lines and the ground. If the three-phase line has a grounded neutral at both ends, then the third harmonic and odd multiples of it all flow at any instant in the same direction in the line and return by way of the earth. Obviously, such unbalanced currents flowing in this way produce very much greater inductive effects on neighboring systems than those due to balanced currents. These unbalanced components of currents which surge back and forth on the line or between line and earth or which utilize the earth as a return are commonly known as residual currents. Their unbalanced character and high audibility combine to make them the predominant factor in the production of noise in telephone circuits.

Leading manufacturers of electrical equipment have become fully alive to the importance of these factors and a great deal is being done at the present time with a view of determining to what extent these sources of inductive interference may be eliminated by proper design of generators and other power equipment. We may reasonably hope for material improvement in this direction in future installations. As to existing equipment, a great deal may be done by well-known methods to reduce the magnitude of these harmonics in power circuits by proper connection and operation of transformers and other connected equipment, and by giving due attention to insulators and the maintenance and operation of switching devices.

In the selection of transformers care should be exercised in avoiding the use of too high magnetic densities, since the use of such high magnetic densities is one of the most prolific sources of harmonics in a power system. Even if the voltage wave of a generator is a pure sine wave the use of high magnetic densities in the transformers may give rise to both currents and voltages of the various higher harmonics for which there is little excuse in practice. Proper connection of polyphase transformers is also important. Numerous combinations entirely satisfactory in practice are known to engineers, so that there is little excuse for introducing serious harmonic disturbances in this way. Grounding should be done only at a neutral point and, as a rule, only one ground on each portion of the network

should be made. Switches should be properly maintained and operated so as to open the circuit as quickly as possible since sustained arcs, even though of relatively short duration, may give rise to harmonics very disturbing both to the power systems and to near-by communication systems.

Even direct-current railway systems may at times be important sources of inductive interference due to the fact that the tooth structure of the armature as well as the process of commutation both introduce high frequency pulsations in the current which have the same effect as the higher harmonics in alternating-current systems mentioned above. In some practical cases these harmonics have been largely eliminated from direct current systems by the use of resonant shunts which form practically short circuits to the disturbing currents without affecting in any way the operation of the power system to which they are connected.

(*b*) *Separation.*—Obviously the severity of inductive interference effects will be reduced by maintaining as large a separation as is reasonably practicable between the power and signal circuits. Long parallels should be avoided insofar as this may be feasible, and where such are unavoidable it has become a well-established principle that, in general, one side of the highway should be reserved for power systems and the other for signal systems in order that the maximum practicable separation may be realized. It should be emphasized here, however, that this idea of separation of lines to minimize inductive interference, while a basic factor in any broad treatment of the subject, nevertheless has serious limitations, and care should be exercised in its application lest an unwarranted financial hardship be imposed on one or the other of the utilities concerned.

(*c*) *Use of metallic circuits.*—One of the most common methods resorted to for reducing inductive interference effects comprises the use of complete metallic circuits for both the power and signal systems. The use of the metallic circuit has long been used by telephone companies for the mitigation of interference between adjoining telephone circuits, giving rise to the well-known phenomenon of cross talk. Wherever power and signal lines are brought into close proximity complete metallic circuits in at least one, and usually in both systems, are absolutely essential to prevent serious disturbances in the communication circuits. Practically all such circuits are now made completely metallic as standard practice, the only important exception being electric railway systems using the rails and ground as a return circuit and rural telephone lines which in many parts of the country are still largely installed as ground return circuits.

(*d*) *Transposition.*—The foregoing remedies, while basic and essential in practically all cases, do not, in general, afford sufficient protection from inductive interference effects, either as between power and communication circuits or between various components of communication circuits themselves. It is found necessary, as a rule, to supplement metallic circuits with proper transpositions of wires at suitable intervals. Such transpositions are often necessary within the telephone system itself in order to reduce cross talk to a desirable minimum, and transpositions in the power lines are necessary in

order to reduce to a minimum the inductive effects which a line may exert on a neighboring system. Theoretically it should be possible by means of proper transpositions to reduce to an almost indefinite extent the voltages induced in communication circuits. In practice, however, this ideal may fall far short of realization unless the transpositions are made with great care and with due regard to the mutual reaction of the two systems upon each other. As stated above, the telephone lines must often be transposed according to a logical system with respect to each other, in order to avoid mutual interference. It is necessary that these transpositions be very carefully coordinated with transpositions made in the power circuits if the full advantage is to be realized. This brings us to one of the most important aspects of mitigating inductive interference troubles, namely, the necessity of properly coordinating the transposition of wires of both the power and communication circuits, and stresses the absolute necessity of full and complete cooperation in this respect if satisfactory results are to be achieved.

(*e*) *Balancing of electrical systems.*—By the application of the methods outlined above it will, in most cases, be practicable to reduce the resultant voltages induced in the communication circuits to extremely small values, such that, if the signal systems are properly balanced with respect to the two sides of the line, the resultant interference with the operation of the communication circuits will not be material. Careful attention, however, must be given to such balancing both in the power and communication circuits, since owing to the extreme sensitivity of the ordinary telephone receiving equipment if such balances are not properly maintained in the several circuits both with respect to each other and to ground, local currents will flow from one portion of the circuit to the other in sufficient magnitude to produce objectionable disturbances in the telephone system.

The measures above mentioned for the mitigation of inductive interference troubles form the essential basis of procedure for dealing with the inductive interference problem and they are generally agreed upon by all as being necessary to its proper solution. However, the extent to which these principles are applied and the mode of application are questions which bring up in practice many points of controversy, the solution of which has presented problems of great difficulty not only to utility companies, but also to State commissions and others interested in the mitigation of this trouble.

We shall now proceed to review briefly the principles and practices that have been resorted to by State commissions in dealing with this problem and endeavor to set forth the present status of the art as regards its relationship to the commissions and to the power and communication companies.

STATE REGULATIONS REGARDING INDUCTIVE INTERFERENCE

It is only within the last few years that State commissions have been called upon to give serious attention to the problem of inductive interference. In the early days of telephone operation the only inductive interference of moment was that due to mutual action by the telephone lines, resulting in cross talk, and this was taken care

of by the telephone companies themselves. In the earlier days of power and electric railway development the parallels were short, loads light, and voltages relatively low, so that inductive interference from these sources was in most cases so small that the telephone companies using metallic circuits were able to protect themselves against it without serious hardship. However, the extension of power lines into interurban and rural districts, with the accompanying increase in loads, and more particularly the adoption of higher voltages due to the longer distances over which power was transmitted, resulted in an increase of inductive effects to such an extent that the communication companies could no longer protect themselves without the cooperation of the power companies. It therefore became necessary to adopt joint measures applicable to both systems. These joint measures, as indicated above, are often interrelated, and consequently there arose the problem of inductive coordination. The problem first reached an acute stage in California, where, owing to the extensive hydroelectric development, many transmission lines of great length and very high voltage extended throughout many portions of the State.

The problem became so serious that in 1913 it was taken up by the California State Railroad Commission with a view of finding a satisfactory remedy. It was evident at the outset that not enough information was available to make it possible for the commission to draw up a set of regulations which would be at all adequate to meet the situation. In consequence of this fact, there was organized under the auspices of the California commission a joint committee on inductive interference. This committee was organized in the early part of 1913 and carried on its work continuously for a period of about six years. During this time many extensive researches covering many different aspects of the inductive interference problem were carried out and a vast amount of valuable data were accumulated. Some idea of the extent and scope of the committee's work and of the complexity of the problem may be gained from the fact that this committeee issued over 70 technical reports dealing with nearly all technical phases of the inductive interference problem. Following the final report of the committee, the California commission drew up and promulgated a set of rules governing power and signal companies for the mitigation of inductive interference. Many of these rules were general in character, providing for proper spacing of conductors, selection and operation of generating and utilization apparatus, and maintenance of proper balances on transmission and communication lines. Some phases of the subject were, however, covered by specific quantitative rules. These related to the distance between transmission and signal lines in close proximity, the intervals at which transpositions should be made, the operation of transformers, and the avoidance of parallels.

The California rules are of special importance, because they have largely been used as precedents by other States in dealing with this problem. A number of States have adopted rules which are very similar in character and scope to the California rules, and while these have met many of the problems involved and have undoubtedly cleared up many perplexing situations, they have not been altogether satisfactory to all the interests involved. The power interests particularly have criticized these rules on the ground that, while they

specify in some detail the requirements that would have to be met by the power companies, they were not equally specific in defining the obligations and duties of the signal companies. There has also been considerable disagreement as to the wisdom of including in the rules at this time any sort of quantitative limitations covering inductive interference. It appears to be the general attitude of the engineers of the telephone interests that enough engineering data is available to warrant the drawing of quantitative regulations covering many of the more important phases of the problem. Power interests, on the other hand, take issue with this view and contend that at the present time only rules qualitative in character are warranted by the existing data.

As previously stated, a number of States have dealt with the matter by the promulgation of regulations. During the first few years following the issuing of rules by the California Railroad Commission these rules were very largely copied by other States, though in most cases changes and some extensions of scope were made. During the last few years, however, the tendency of States that have dealt with this matter has been toward greater conservatism and to avoid specific quantitative requirements. Up to the present time nine States have taken action of one kind or another with a view of mitigating inductive interference troubles. Of these, six have issued rules based largely on the California regulations. In all of these latter sets of regulations some of the rules are general and qualitative in character and others specific and provide quantitative limitations. The Indiana commission has more recently promulgated a set of regulations general in character, all specific quantitative requirements having been avoided. The Oklahoma commission has taken a still more reserved position and has thus far issued only tentative instructions which are intended to serve as a guide for power and telephone companies and do not at present have the status of regulations.

GENERAL PRINCIPLES

We have thus far dealt only with the strictly technical aspects of the problem of mitigating inductive interference. From the standpoint of State commissions the inductive interference problem presents three main aspects, namely, technical, economic, and legal, and these several aspects are mutually interrelated. It is possible to eliminate substantially all inductive interference effects by the application of one or more technical measures already well known. The difficulty arises from the fact that, in general, the application of these technical measures may, unless properly coordinated, lead to excessive cost. One phase of the problem before the State commissions, therefore, is to see that technical measures are properly coordinated and applied so that no undue hardship will be placed on any one utility company and the total cost ultimately passed on to the public will be as low as practicable. This principle has been fully recognized by the various commissions that have given attention to the problem, but only in one set of regulations has any specific provision been included to cover it. The Ohio regulations provide that wherever two or more methods for mitigating inductive interference are applicable that method or combination of methods involving the least total cost shall be adopted regardless of the system to which they must be applied. This principle

is fundamentally correct and has met with general favor on the part of both power and communication companies. It will undoubtedly find wide application in the future except where barred by legal limitations to be mentioned later.

APPORTIONMENT OF COSTS

Another question that frequently arises in the practical application of the methods of mitigating inductive interference is that of the division of costs between the utilities concerned. Some States provide explicitly in their rules that such apportionment of costs shall be made by agreement between the utilities themselves if this is possible, but if such agreement can not be reached, the matter is to be referred to the commission for decision. At least one commission, namely, that of Iowa, has stated that, in general, where the telephone line is the prior occupant and where changes, such as conversion from ground return to metallic lines, moving of lines from one side of the highway to the other, and providing proper transposition, are necessary to avoid interference troubles, these changes will be made and the costs charged to the power company.

SUPERIOR RIGHTS

There is one legal aspect of the question which has a direct bearing on the matter of the application of the principle of least cost and also on the apportionment of costs, and this is the question of superior rights. Presumably this question will arise only in the case of interference between communication circuits and railway lines. There is a well-established principle sustained by numerous court decisions that any utility company which, in its normal operation, facilitates traffic along a public highway occupied by it has a superior right to the use of such highway and is not liable to the same extent as a power company for interference with the operation of a communication circuit. This is true even though the communication circuit may be a prior occupant of the highway.

AGREEMENT PRIOR TO CONSTRUCTION

There is another basic principle, namely, that of agreement between power and communication companies in advance of construction, which is vital to a proper handling of the inductive interference problem. This principle is in reality a corollary to the principle of least cost. In practically every case the inductive interference can be taken care of more economically if the necessary measures are built into the lines at the outset than if introduced at any later time. This principle has been recognized and often applied by mutual agreement between power and communication companies themselves. It is probably with this principle in view that most of the commissions promulgating regulations to date have included a clause requiring that advance notice of construction be given to the other parties affected.

As regards the matter of advance notice of construction, it is perhaps well to distinguish here between advance notice to the commission and advance notice to the other party concerned. As a

rule, the latter is sufficient and in most cases, with proper cooperation, will permit the use of properly coordinated measures that will eliminate materially inductive interference. Only in those cases in which the utilities are not able to reach a satisfactory agreement between themselves is it necessary to have the matter referred to the commission. By following this procedure the commission can relieve itself of a tremendous amount of unnecessary detail which would devolve upon it in case advance notice of all construction were required to be made direct to the commission.

MUTUALITY OF INTERFERENCE

From the standpoint of the public and, therefore, from the public utility commission, the subject of inductive interference can not be treated merely as a question of interference by one utility affecting the quality of service supplied by another. This latter aspect of the question must, of course, always be kept rigidly in mind in justice to the utilities concerned, but it is important to bear in mind also that in its ultimate aspects it is a question of interference between two services, both of which are essential to the public, and, therefore, in providing rules or requirements which are designed to mitigate troubles growing out of interference it is necessary to exercise care lest the burden of avoiding interference with one class of service may impose serious and unwarranted restrictions on providing the public with the other class of service. The broad principle here involved has been clearly recognized and expressed in a number of commission documents and many court decisions, but it has not yet found expression in any set of commission rules with which we are acquainted, except, perhaps, in that clause of the Ohio rules which provides that the mitigation must be brought about by that method or combination of methods involving the least total cost.

RECENT DEVELOPMENTS

During recent years it has become more and more evident that such rules as have been promulgated in the past, while undoubtedly accomplishing much good, have not been adequate to meet the demands of practice, and, furthermore, that there is not at present available sufficient technical data to warrant the drawing of rules that will be sufficiently comprehensive and specific to meet requirements. The general tendency on the part of communication interests has been to press strongly for more specific regulations, they believing that enough data is available at least to warrant going considerably further than we have yet gone in the direction of formulating quantitative rules. The power interests, on the other hand, have energetically opposed this view, they deeming it necessary to study the subject in a more comprehensive and thorough manner before it can be properly dealt with by regulatory bodies. It became more and more evident that in order to reconcile these views not only must more technical data be made available, but better and more effective means of cooperation between the interests concerned would have to be brought about. Until recently effective cooperation between the power and communication interests in the solution of this difficulty has been rendered difficult, partly

because of lack of mutual confidence based chiefly on lack of acquaintance and partly on the comparatively loose organization of the power interests.

For some years past, however, there has been a growing appreciation on the part of leading executives both of the power and communication interests of this unsatisfactory state of affairs. They have come more and more to recognize that the mere promulgation of rules based on insufficient data will not only fail to solve the problem, but will lead to the establishment of dangerous precedents. Furthermore, they have come to appreciate that even good rules without the proper cooperative spirit will be useless. In consequence of the better appreciation of these fundamentals there has been a gradual drawing together of the power and communication interests which has resulted recently in the appointment of a joint general committee to deal with the physical relations between electrical supply and signal systems. This committee represents the National Electric Light Association and the Bell Telephone System. It has been actively engaged in working out a fundamental basis for the ultimate solution of the inductive interference problem. The objects of the committee as set forth in its first report, issued March 7, 1922, were threefold—first, to develop general principles on which effective coordination between the two interests must be based; second, to develop standards of construction and operation in accordance with such principles; and third, to carry on such research work as may be necessary to reduce as far as practicable both the inductive influence of power systems and the inductive susceptibility of power-communication circuits. The committee issued a second report dated May, 1922, and a third one dated December, 1922, the latter being only recently made available. This third report sets forth in considerable detail certain basic principles and practices essential to a proper treatment of the inductive interference problem. It also emphasizes particularly the joint nature of the problem and the mutual responsibility of the two classes of utility companies in dealing with the problem. Full and complete cooperation is urged in order that adequate coordination so essential to the treatment of the inductive-interference problem may be realized. The report recognizes that wherever two or more methods of eliminating inductive interference are available, that method or combination of methods which affords the best engineering solution should be adopted. This principle is substantially identical with the principle of least cost already discussed.

Another important principle set forth in the report is that of mutual tolerance on the part of the two utilities of each other's presence on the same highway, it being frankly recognized that the interests of the two utilities themselves, as well as of the public, will be best served by the utilities making such concessions as to permit joint use of highways wherever possible.

The development of this new cooperative movement has, within the last year or two, changed completely the entire aspect of the inductive-interference situation, and the importance of the work of the joint committee that has been the outgrowth of this movement can hardly be overestimated. Although it has been in existence for little more than a year, its accomplishments to date mark one of the

biggest steps that has yet been taken toward the ultimate solution of the problem of inductive interference. The work of this committee has been of great value in developing mutual confidence on the part of the different utilities and the spirit of cooperation between them. The principles and practices already promulgated by the committee will go far toward laying an effective groundwork for the ultimate and satisfactory mitigation of inductive-interference effects. The importance of the committee's work is augmented by the fact that it is a national committee and, therefore, in position to secure the advice and counsel of nation-wide interests and to view the entire problem on a truly national scale. It is, therefore, in position to command the confidence of local utilities throughout the country so that its findings are very likely to be adopted and used in the same cooperative spirit which the committee is displaying in working out the solution of the problem. Undoubtedly, the work of this committee when finally completed will afford a firm and satisfactory groundwork on which to base not only general regulations, but details of procedure and practice under practically all conditions.

DISCUSSION OF PROBLEM OF INDUCTIVE INTERFERENCE

Mr. Crittenden. Mr. McCollum has indicated the futility of legal action and the advantages to be gained by cooperation in dealing with these technical problems. Because this correlation of effort has been so successfully inaugurated, we have present this afternoon representatives of two interests which might be considered as opposed—the National Electric Light Association and the American Telephone & Telegraph Co. I will call on Mr. W. J. Canada, of the National Electric Light Association.

Mr. Canada. Mr. McCollum has given a thorough, concise, and well-balanced résumé of all phases of the inductive interference problem. I can only emphasize two or three points that appear likely to be of particular prominence for the next year or two at least. One of these is the departure from the purely legal standpoint in dealing with inductive interference problems. When the problem came up it came so suddenly, and being little understood, provoked so much apprehension and misapprehension, that the quickest method seemed to be to resort to the courts. At present the utilities are endeavoring to establish a better basis for understanding and treatment of these inductive relations without recourse to old legal precedents such as govern court decisions. Our present course in development of principles and practices is in conformity with the theory of modern public-utility law, which provides for a constantly progressive guardianship of the public interests by a commission which makes and modifies the requirements for practice as the times demand. This gives opportunity for the settlement of problems where progress goes too rapidly for courts and court precedents to keep up with it.

In the past few years we have been seeking the cure, rather than simply naming and analyzing the difficulty. Instead of the "inductive-interference" problem, we have started calling it the "inductive-coordination" problem. In approaching the subject from this cooperative standpoint we bring out many facts formerly withheld for defensive reasons. Also, by thus bringing both power and

signal points of view into frequent and friendly contact, we are bringing out of obscurity many important considerations. Inductive influence, susceptiveness, and coupling are being considered and analyzed as physical factors and not as blameworthy qualities. Just what treatment each factor should receive depends upon the economic solution. Just how each factor may be treated and how much advantage may be derived by applying one or another method in varying degree is the subject of our present study. Our recommended treatment in control of different factors will be aimed at producing the best results in all services at an overall minimum of cost, generally applicable treatment being, of course, preferred to specific treatments which merely tend to delay cost and controversy.

As Mr. McCollum stated, there has been for some two years going on between the lighting companies and the Bell system a very large and very effective cooperative movement. At first there was some tendency to try to draw up quickly some quantitative provisions. These are certainly needed in field work in order to avoid argument and produce results economically, but with considerable restraint on the part of both the power and signal groups the joint committee refrained from doing this, and tried instead to get at the problem more fundamentally and to arrive at broad principles which could afterwards be expanded into recommended practices without necessity for going back over the early work and amending results too hastily arrived at. The joint report made in May, 1922, included principles which had been given a considerable test by applying them to numerous situations and which seemed to be essentially fair and sound. After putting them up for discussion and trying them out in many fields and giving opportunities for criticism by many interests, particularly the engineers of commissions, it seemed certain that they were in fairly good shape to build upon further. A more detailed interpretation of these principles was next prepared which constituted the joint report of December, 1922. There was again considerable tendency toward introducing quantitative provisions before the treatment of all factors could be settled. Again, however, that tendency was avoided by mutual restraint and an effort was made to assure against losing sight of any of the principal factors which should enter into the settlement of individual problems or into general solutions. Our aim was to include a brief qualitative treatment of each important subdivision into which the factors contributing to inductive relations between circuits could be classified. How well that purpose has been fulfilled, of course, remains to be seen.

The next piece of work ahead of our joint committee evidently is to build up some quantitative treatment of the factors which are now laid out as those to which control treatment should be given. This task involves a number of considerations. It involves important economic considerations, and these require scrutiny from more viewpoints than do the underlying technical and ethical questions. Every wire operating organization—power, signal, transportation—should be afforded full opportunity for sharing in the presentation of economic considerations involved. Facts, rather than assumptions of special privilege, should govern the solutions and no class of service user be under or over favored.

As Mr. McCollum also indicated, the question of the best use of our highways is one of the most important questions. Highways are sometimes considered by the courts in the more narrow way of being traffic channels only, but there is an increasing tendency toward considering them as routes for rendering public services. In most cases we have investigated we find that the people are more economically served by maximum use of highways than they were formerly by the separation of services into diverse channels. This consideration of most economic use of highways (including railroads which have been declared highways) forms a very convenient criterion as to the kinds of facilities to be recommended on a line of highway between centers of population or tributary to many dwellings or workshops.

The work immediately ahead in the joint committee has been divided into subcommittees. One is the subcommittee on further development of rules and practices. For quantitative development there is needed a very considerable amount of field work. In spite of the history of the matter, we have comparatively little data on the existing field conditions to show why some of the thousands of existing inductive exposures between lines are workable and trouble free, while a few others, though roughly similar, are not workable.

There is also a subcommittee on development and research being formed to inquire into various factors which contribute, respectively, to interference and coordination.

I believe that there is much more work needed in the near future among some other classes of utilities, particularly for the sake of building up groups of engineers in those utilities who will understand the technical questions involved and can intelligently join in a cooperative method of procedure for inductive coordination. Some of the economic considerations of street railways, railroads, etc., would be somewhat different from those of power and signal utilities, although the physical considerations would be more or less alike, but the main reason for work by these other organizations is to keep our procedures on a cooperative basis. That is the thing that is needed and that the public expects of its utilities.

Mr. Crittenden. We would be glad also to hear from Mr. Wilkinson, of the telephone company.

Mr. Wilkinson. Mr. McCollum has summarized the inductive interference or inductive coordination situation in a splendid way and has probably treated it more fully and more completely than has ever been done at one time before. Mr. Canada has covered practically all of the other phases of the problem which come up in practice, and between them they have left very little for me to say.

The National Electric Light Association was born about 1885 in Chicago, and at its very first meeting one of the things that was taken up was a letter from a telephone company complaining that telephone service was being disturbed by a power line. The two interests did not then, of course, realize what they were up against, but if there could have been full realization of the importance of the problem at that time, we might not have to be discussing the matter in such detail to-day. However, the telephone companies had enough difficulties of their own in the early days because of the

naturally rather primitive equipment that was then in use. As the telephone plant grew and developed, we took care of the mutual inductive problems in our own plant, and we thus to a large extent took care of the problems that would have arisen otherwise from what we may call "outside sources." Then the power companies started to grow by leaps and bounds, and it became apparent after full study by telephone engineers that the problem can not be solved by making changes in the telephone plant alone. It became more and more apparent as time went on that it was a mutual problem, and that it could not be solved by each party trying to place the blame on the other. This was tried for some time and it naturally led the companies further apart, and brought them to the point where they were considering the advisability of letting the courts decide the matter.

Of course, this was not the general case, but there were enough cases of acute controversy so that the two utilities were brought to the realization that if they wanted to get the right answer they must treat inductive interference as a mutual problem and solve it by methods of inductive coordination determined by joint study and investigation. Naturally, it is only by such cooperative method that the two utilities can properly meet their service requirements.

As Mr. McCollum has pointed out, there are two main parts to the technical problem. One, the investigation of the causes and effects of inductive interference brought about by the proximity and character of the lines, and two, the methods of coordination to prevent the interference. From the operational side, in order that the information which technical research brings out may be applied to each particular case it must be applied in accordance with the best engineering solution which, of course, includes the necessity of rendering proper and efficient service of both kinds. Mr. Canada and Mr. McCollum both pointed out to you the work of the joint general committee of the National Electric Light Association and the Bell Telephone System. The work of that committee, looking toward the proper engineering solution of this mutual problem of coordination, has showed that both utilities can develop their respective systems and give adequate and efficient service without undue difficulty or interference. Cooperation and advance planning are rapidly bringing about effective coordination. Through such work the utilities can plan together for the most effective and economical scheme to care for future coordination, as well as to make arrangements to clear up in an orderly and systematic way existing unsatisfactory conditions. Through such advance planning it is found there is plenty of room for both companies to give adequate and efficient service. Where considerations of safety, service, and economy make joint use of poles desirable, such arrangements should be made, and it is found that this can be done with a great many of the lines. Then there are certain classes of lines where joint use is not so desirable, but the lines can be properly operated on opposite sides of the highway. This leaves only the higher voltage transmission lines and the longer toll lines where the consideration of more than highway separation enters into the problem, and where separate routes may be required. These latter lines, while sometimes giving rise to difficult problems, only represent a small part of the total line mile-

age, and it is generally found that there is sufficient room to work out a proper solution.

Where the question of principles and practices for coordination has come up before the State commissions, I want to say that the utilities feel that they have had the fullest cooperation, and in these cases you gentlemen have done a great deal to assist in the advancement of the solution of our difficulties. Thank you.

Mr. CRITTENDEN. The question is now open for general discussion. The engineers of the State commissions must have had some experience with this problem. We would be glad to hear from them.

Mr. BLACK. I might say in the beginning that we have fallen for the joint report of this committee. We took the rules as they state them here and changed a few clauses in order to fit our case, and we require the utilities in the State of Maine to report along the lines suggested here. We leave out the question of payments, but we require that the power companies and the telephone companies shall get together and follow the general principles laid down in this particular report of the joint committee, and then if they can not agree as to the payment of expenses they have the option of referring that back to the commission. We have simply made these suggestions mandatory upon the utilities in the State. We have stated a policy in regard to the location of lines and types of construction and have made the utilities do what they should have done without any complaints.

Mr. TOEPPEN. We are at present drafting a new set of rules in which the report of the committee will be incorporated, probably not as independent sections but merged with the old ones. We do not call attention to interference as a special problem, but make the taking care of it just a part of good construction practice throughout the State. This will apply to the small company primarily. With the two large companies, the Detroit-Edison and the Consumers, we have never had any arguments as far back as I can remember, but we have had a few small cases in the last two years. We have not had any real inductive interference problems in the State of Michigan.

Mr. SNOOK. There is one point that was brought out last by Mr. Wilkinson that has given us the most satisfaction; that is, compulsion of advance planning. I had a man say to me, "Your code sounds too much like the Bible." Yet his company found that if plans are taken care of in the right way there won't be very much trouble when it comes to the final consideration.

Mr. CARTER. Last November the Indiana commission put out a pamphlet taking care of this matter. We have several hundred independent telephone companies. The commission felt, and I felt, in working up a set of rules, that a very brief, concise statement would be better than to try to work out elaborate technical plans. We got it out and it has worked out very well. We have solved several problems that we had not been able to solve before. The electric and telephone interests have gotten together and have gotten into agreement to a very large extent.

Mr. CRITTENDEN. Do the railways, electric or steam, come into this problem?

Mr. CANADA. It is only in respect to the proper economic solution that the inductive coordination problem between electric lines of different utilities varies. At present the technical solution could

apparently be exactly the same, but the proper quantitative application of control measures for various factors in power and signal circuits and in their couplings would differ as between highways and railroad right of way, because of the different dimensions, the public *vs.* private ownership, the character of development of land at either side of the way, etc. We might find it proper to make quantitative differences of predetermined degree, between the application of control measures under one or another right of way conditions or according to the character of public or private use to which the electrical systems concerned are put. In arriving at these proper quantitative solutions (and our joint work has not yet included these) there is no doubt but that additional cooperation of electric and steam railroad representatives should be secured.

Mr. SNOOK. On my way to Washington a prominent railroad man described to me their installations with telephone lines on trolley poles. He said that in most cases this would not be practicable, but for the particular kind of construction which they had it was the most economical thing for them to do.

Mr. KNOWLTON. It seems to me that the two associations, while they represent a very large per cent of the utilities in the country, can not speak for all of them, and I am just wondering how their results can be gotten to the stage of an authoritative rule, one that can be adopted by every company and by the commissions. There is hardly opportunity for any one company to do the thing as thoroughly as they intend to do it. The question is, then, will it be possible to adopt the different conclusions they arrive at, or should there not be some consideration of our special administrative problems in formulating these as formal rules? There is also another question, should the State commissions make investigations of their own, or should they have a hand in the present study of inductive coordination?

Mr. WILKINSON. When we completed the work on these reports, we sent copies to the president of the United States Independent Telephone Association. It is very interesting to note that of the last issue we sent him 200 copies and he wrote back and wanted more. He wanted to put them in the hands of the small telephone companies throughout the country and asked us to send him 1,000 copies more. In this way we are endeavoring to make this information generally available throughout all branches of the industry.

Mr. SNOOK. In regard to coordination between the Electric Light Association and the Independent Telephone Association, it would help along the line of coordination if the telephone people could know what the electric-light people plan to do, and vice versa.

Mr. CANADA. I am glad that the question is raised. About a year ago the United States Independent Telephone Association, at its Chicago convention, invited both Bell and National Electric Light Association organizations to be represented and to present companion papers on inductive interference and its prevention. This was for the professed purpose of promoting a mutual understanding and so furthering cooperation. Similar representation of the National Electric Light Association at State telephone conventions has been frequently requested and arranged where practicable. These ex-

changes have been supplemented by a permanent assignment by President MacKinnon of an independent telephone representative, Mr. Dearing, of Des Moines, to keep constantly in touch with the National Electric Light Association's work on this subject and so facilitate mutual agreement in development of methods and in handling individual problems.

We might as well understand, however, that this does not fully represent the educational problem among small telephone companies. While the Bell System represents all Bell companies, and the National Electric Light Association a very large proportion of all power utilities, the proportion of independent companies represented in the independent associations is small. Furthermore, the independent associations themselves are loosely knit and have neither adopted consistent and far-sighted policies on such joint problems of coordinating public-service facilities, nor developed machinery for carrying out such policies. This difficulty is fully appreciated by them and we shall do all possible to make our cooperation stronger, more consistent, and more in the interest of both kinds of service users. The State commissions appreciate this situation. If the association of telephone companies supports a mutually acceptable plan of cooperation and inductive coordination, the unassociated telephone companies will undoubtedly adopt similar practices. Education along these lines appears to be the province of the telephone associations with whom the National Electric Light Association and Bell System will cooperate in the first instance and as fully as organization limitations permit.

Mr. Hayden. In regard to the dissemination of information which Mr. Canada and Mr. Wilkinson spoke about, at the last annual convention of the Wisconsin State Association Mr. Canada and Mr. Grace, of the American Telephone & Telegraph Co., talked of this same cooperation and the effort that was being made to determine a final solution. I will say that the Wisconsin Railroad Commission has never laid down any rules on inductive interference just because we felt that we did not know what requirements to make. We did not know what rules to lay stress upon. We did not have the engineers, and did not have the experience necessary to carry out the program properly. We are looking to this very cooperation and the work that is being done to give us our foundation for such rules as we may find are necessary to lay down. In the meantime we have somewhat arbitrarily established a rule that telephone and supply lines shall not occupy the same side of the highway in the rural districts, except where it is not practicable to do otherwise. We can get along with such rules until more definite ones have been formulated. Such talks before the Independent Telephone Association and before the Electric Light Association have brought about, we think, the understanding that the utilities should consult with one another before they construct a new line.

Mr. Snook. We have rules in regard to the location of lines. We have had the question up with the Ohio Electric Light Association, the Independent Telephone Association, and some of the officers of the Bell Telephone Co., and it was agreed that to require obtaining the commission's consent before commencing construction would be futile, because of the enormous number of such cases. If such a rule

were made, it would require an army of inspectors and engineers to be effective.

Mr. HAYDEN. I believe that a little notification beforehand will save a whole lot of correspondence later on, and I believe that if we had notification beforehand we could determine by quite a casual analysis whether there would be bad inductive interference. Advance notice to the commission is important. Notice should also be given to the other utilities. Then, if it is seen that there is likely to be a real problem, the utilities could settle it between themselves, and if they can not do that they can take it up with the commission.

Mr. CAMPBELL. In Iowa the board of supervisors in each county may grant a franchise for a right of way, or the railroad commission may grant this, just as the applicant desires. A great proportion of our trouble comes from lines granted franchises by the supervisors. As a general thing, the supervisors in the rural counties are not in a position to pass on the matter of whether or not a line is hazardous. They look upon it as simply a matter of using the highway. I do not think advance notice is necessary so much for telephone lines because most of them are now built, but if something can be done which will not be too great an inconvenience to let the commission know just where new power lines are going to be built, so that advance planning can be taken into consideration, one of the greatest sources of our trouble will be removed.

In Iowa I can safely say that there is a marked improvement when the people at large know just what is being done from a cooperative standpoint. We still have a situation which is not solved. The telephone proprietors who are not members of the independent organization are difficult to reach. For instance, in one county we have 37 separate telephone companies all owned by farmers, and many of them still insist upon a full observance of their legal rights. There are plenty of attorneys they can consult who will tell them that that is the thing to do.

Mr. BLACK. We had an 11,000-volt line which paralleled the Western Union, and the matter came to the attention of the commission. The commission had no rules at that time in regard to it, so we took it up with the power company, and the line was moved to another place just as satisfactory to the power company.

We are in difficulty in Maine because the selectmen in each town specify the location that the power company should have, but we do have the advantage that in case the selectmen in the town require something that the company does not feel it can give the company has the right of appeal to the commission and then to the supreme court.

Mr. TOEPPEN. In addition to the matter which Mr. Black mentioned, I think the thing that is really needed to make the final connecting link, especially in dealing with the small companies, is to have a man on the commission staff who shall act as a sort of liaison officer. We have such a person in the telephone section and are looking for the same kind of man for the electrical section, one who can bring the companies into line, because John Jones, the commission man, who is a good friend says, "Jim, this is a good thing, and the thing you ought to do."

Mr. Wolf. In Maryland we have made no rules. We have preferred to leave the matter of inductive interference for treatment by the utilities along cooperative lines, such as those of the National Electric Light Association and the American Telephone & Telegraph Co. We have taken the bull by the horns, so to speak, and got something done in another way by encouraging the small organizations to sell out. We have been rather successful in getting rid of some of the weaker sisters. We have not been able to get rid of them all.

One other thing. We had a meeting recently and called all the utilities of the State together and formed an organization, which includes not only the gas, water, and electric, but the telephone utilities, and we hope to have all the smaller telephone companies included.

Mr. Crittenden. We will pass to the last item on the program for to-day, which involves a variety of problems on the grounding of electrical circuits. I will ask Doctor Lloyd to give an introductory statement on the question.

GROUNDING OF ELECTRICAL CIRCUITS

By M. G. Lloyd, *Electrical Engineer*

The grounding of electrical circuits is instituted in some cases for operating reasons and in others for protective reasons. A third consideration which may influence this practice is its effect upon inductive interference between power and signal (telephone and telegraph, etc.) circuits. The public utility commissions may be concerned with grounding as it affects inductive interference and as it affects the operation of power utilities, since this will have an effect upon the service given; but it is my purpose to discuss only the grounding which is carried out for protective purposes since our staff here at the bureau has not made any study of grounding from the two other viewpoints.

Grounding for protective purposes applies both to low-voltage circuits and also to the noncurrent-carrying metallic parts of electrical equipment. Such grounding is called for by both the National Electrical Safety Code and the National Electrical Code of the Fire Underwriters. The grounding of the frames of machinery, the cases of equipment, conduit for wiring, and similar metallic parts is required to be carried out whenever the voltage of the circuit exceeds 150 volts, and is desirable in all cases. The purpose of this grounding is to insure that such exposed parts will never be at a potential much higher than that of the ground, even though there should be a failure of insulation which would bring them in contact with the circuit and thus make them alive.

The grounding of the circuits themselves is called for whenever the normal voltage is comparatively harmless and there is a possibility that a higher voltage may be imposed upon the circuit by a breakdown of insulation or unexpected contact with wires of foreign circuits. The exposure to circuits of higher voltage may be brought about through connection to a transformer or by connection to an overhead outdoor line. Even where there is no such exposure it is

desirable to ground the neutral of a three-wire circuit in order to reduce the maximum possible potential of the circuit above the earth.

Heretofore both of the electrical codes have required that independent ground connections be made for the circuits and for the noncurrent-carrying parts of equipment. The objection to a common ground connection is twofold. In the first place, if this ground connection should be interfered with, the voltage of the circuit may be imposed upon the exposed metal parts and thus a possibility of shock through accidental contact be introduced which would make the conditions more hazardous than if the grounding had not been attempted. In the second place, even though the ground connection remains intact, any drop of potential on the grounding conductor due to the flow of current from the circuit to the ground would be effective in raising the potential of the exposed metal parts above ground potential, and thus promote conditions for shock at the time such current was flowing. Thus, if the resistance of the grounding conductor and the ground amounted to no more than 4 ohms, a flow of 30 amperes would raise the voltage of the conduit system, cases, etc., to 120 volts above the ground, which is not a desirable condition.

Where there are sufficient grounds on a system, as, for instance, a ground at each service entrance of a group of buildings all fed from one transformer or one interconnected secondary system, the first of the above objections disappears, since the possibility that all ground connections will be lost is decidedly remote. A proposal has consequently been made and is now under consideration in the revision of the National Electrical Code that such a common ground be permitted whenever three or more services on the same secondary system are grounded to metallic water piping. This proposal ignores the second objection mentioned above, since that objection will still apply to the situation thus created. On the other hand, it should be kept in mind that in certain municipalities this practice has already been in vogue, and so far as I am aware little or no trouble has so far been experienced.

A particular instance of the grounding of noncurrent-carrying parts comes up in rule 213 of the National Electrical Safety Code, which requires the grounding of guy wires upon high-voltage lines unless an insulator is inserted in the guy which is effective against the line voltage. The rule at present is applicable in urban, but not in rural districts. Perhaps this rule should be extended to rural districts inasmuch as an accident occurred in Maine about a year ago from contact with a live guy wire which resulted in the death of three persons.

DISCUSSION OF GROUNDING OF ELECTRICAL CIRCUITS

Mr. Snook. In the case of joint construction with signal lines, it is sometimes necessary to swing a transformer below a signal line, and we must determine what to do to make it safe for the telephone lineman. What would be your suggestion?

Mr. Hayden. I think the code covers that. The transformer leads would be in conduit.

Mr. Snook. What kind of conduit?

Mr. Hayden. Put them in iron conduit.

Doctor Lloyd. In a situation of the kind Mr. Snook mentions, it is desirable that the case of the transformer be grounded for the protection of the telephone lineman. Otherwise, if there should be any breakdown the lineman would be exposed to the high-voltage line in his own low-voltage work. On the other hand, in order not to carry that ground up to the neighborhood of the high-voltage conductors above, it seems to me that the high-voltage leads coming down to the transformer should be placed in insulated conduits instead of metal conduits. It seems to me that gives sufficient protection to the telephone linemen.

Mr. Wilkinson. Ordinarily in joint pole construction it is customary to locate a transformer above the telephone attachments. It is then not necessary to run primary and secondary wires vertically through the telephone space, and thus the telephone lineman does not find it necessary to work around such wires or around the transformer itself. However, there are occasional cases in factory districts where the amount of power needed in an individual location requires the installation of a transformer too large to be located near the top of the pole. Where it is necessary to place such transformers on the poles a satisfactory arrangement is to build an H fixture with a platform between two poles to carry the transformers. The telephone lineman does not then have to come in contact with them in climbing the pole. Furthermore, an arrangement of vertical runs to such transformers can be so made that the telephone attachments are avoided, and the telephone lineman can keep at a safe distance from such vertical runs.

Mr. Black. In considering the adoption of the National Electrical Safety Code in Maine the local utilities objected to the requirement for grounding and took specific exception to rule 213 (*c*), part 2 of the National Code, which reads as follows:

> The anchored end of the guy wires attached to wood poles carrying lines of more than 15,000 volts shall, except in rural districts, be permanently grounded (see sec. 9) wherever this part of the guy has a clearance of less than 8 feet to ground, unless an insulator is used which is permanently effective against the highest voltage which is liable to be impressed upon it.

We have a rather peculiar situation in Maine. There is one company that has a 13,000-volt power line, with their poles set in a gravel base, and they have asked how they are going to get grounding. (Reads extract from letter):

> In our particular system we operate 38,000 volts with the transmission in Y and the Y point permanently grounded. As a result of this permanent ground we find it impossible to operate any of our lines with the wire off the insulator and touching a cross arm, and in all cases where such a condition occurs our lines will trip out immediately. It, therefore, appears that under the condition of any of our transmission wires coming in contact with a guy wire, even with high resistance to ground, the same conditions would be obtained, namely, that the switch would trip immediately.
>
> We, therefore, feel that for companies operating as our company with a grounded transmission system, that we should be exempted from maintaining the grounds on guy wires with a resistance as low as 25 ohms.

I would rather like to get the ideas of some of you gentlemen in regard to that particular point: whether it is necessary or not to ground guys when you have a transmission system in Y and Y point permanently grounded.

Doctor LLOYD. Was it on that particular system that you had that accident when the distribution line came in contact with the guy?

Mr. BLACK. No; the condition was this: A 33,000-volt line had been built over a 2,200-volt distribution system. For some reason or other at the time they were built the transmission line was owned by one company and the distribution line by another. The distribution line had been allowed to go. They had not paid any attention to it. Finally the pole tipped over. The 2,200-volt line came in contact with the guy on the 33-000-volt line. A man came along driving a horse. I am not certain, but I think the horse stepped into a puddle of water, as it had been raining. The man went to help the horse, and another man went to help him and they were killed. Then a woman went to help and she was killed. No one standing around them knew what happened. We measured the resistance and found something like 900 ohms. It was very high, but I do not remember the exact figures. In that particular case we searched around to find means of grounding, and did finally locate one that came within requirements, but it was quite a job to find one which gave the desired resistance.

A MEMBER. What was the reason for wanting to ground it?

Mr. BLACK. We thought if the wire came off the insulator and touched the cross arm, the circuit breakers would throw the line off immediately.

Doctor LLOYD. That means that they get a good enough ground on a wood cross arm to throw the circuit breaker on the 2,200-volt system?

Mr. BLACK. No; the 38,000-volt system. In some locations their system is not grounded.

Doctor LLOYD. Would this company object to running an overhead wire to a point where they could get a sufficiently good ground?

Mr. BLACK. Most of the companies in the State seem to object to it. One company has built an extension to its line with every pole set in a granite ledge, and they are probably hunting for some place to ground it. We had one case of electrocution because of an overhead ground system. The wire came in contact with the 2,200-volt distribution system. The ground was not effective, and the reason why the accident happened was that the space between the transmission wire and the ground wire itself was very small, and a boy swinging on the guy brought them in contact and was killed. There were five points where the system was supposed to be grounded. It was an exceptionally dry summer. The ground plate was buried in charcoal, but it was dry as a bone. That accident came about by an attempt to carry such a system.

Mr. TOEPPEN. We have had two fatalities in Michigan in the last two months when the 11,000-volt distribution line came in contact with the telephone line.

Mr. BLACK. Do you consider insulation as a practical proposition for these high-voltage lines?

Mr. TOEPPEN. I think so. I would take my chances on poor insulation. I would rather have a broken, interlocking insulator than bad grounds.

Mr. BLACK. The principal objection is the cost of maintenance.

Mr. TOEPPEN. I would rather have the expenses than a law suit.

Mr. Black. It would make a difference as to how many miles of line you had to maintain.

Mr. Imboden. For some voltages there are various opinions as to whether or not it is desirable to have a common ground wire carried throughout the entire system, but as far as grounding a guy is concerned, if you can not get an adequate grounding of guys, it is absolutely essential to carry the overhead ground to some point where you can get it.

Mr. Black. One company has suggested that the requirement for grounding or insulation of guy wires attached to wood poles should not apply to rural districts. Perhaps we may solve our problem through a definition of "rural districts." What is your answer, Doctor Lloyd?

Doctor Lloyd. Where it is so expensive to insulate the guy on these high-voltage lines and expensive or impossible to get a ground, it is best to try to get rid of the guy. Wouldn't it be less expensive in the end to place the poles at short enough distances so that they do not need guys or possibly use an H frame? It seems to me that after all that might possibly be the cheapest way out of it. Poles are not expensive up in your country.

Mr. Imboden. Doctor Lloyd's suggestion has been carried out very extensively in Ohio and West Virginia by using A and H structures, except in cases where such structure would be unsightly. Then we used the guys.

Mr. Black. Has anyone had any occasion to consider the point of whether or not the grounded transmission line should be exempted from grounding the guys attached thereto?

Doctor Lloyd. That would not take care of the accident hazard if that particular line was not in trouble itself, although it was one of these guys that made contact. The very ground that causes the circuit breaker to open may be due to somebody in contact, and even in the act of opening up the line that person may be killed.

Mr. Black. It is also a rule with some companies that the operator shall close the circuit, after it has been thrown out by the circuit breaker, to determine whether or not the line has cleared itself in the meantime. I think I have a pretty good idea as to what your experience has been and thank you very much.

Mr. Crittenden. I would suggest that questions like these be formulated as concisely as possible, and that we begin our session to-morrow with a discussion of experience in the various States. The meeting will be called at 10 o'clock to-morrow morning at the Bureau of Standards. Unless there are other things we should take up this afternoon, this session will now close.

THIRD SESSION (MORNING OF SATURDAY, MARCH 3, 1923)

The conference reconvened at 10 a. m. at the Bureau of Standards, Mr. E. C. Crittenden presiding, and continued the discussion which was begun at the preceding session.

DISCUSSION OF GROUNDING OF ELECTRICAL CIRCUITS (CONTINUED)

Mr. Hayden. The things I am particularly interested in are the necessity of the ground on secondaries being properly made and the question of the grounding of the secondaries where you have three-phase distribution leading from a distribution network. In the State of Wisconsin we have a great many small communities where there is a considerable amount of power used. Motors are operated on three-phase circuits, and the lighting is taken directly from the three-phase secondary. The lighting is 110—220 volts on the three phases, and it would then be impossible to ground in each of the premises. Now the question arises whether the best plan would be to require the utility to put a larger transformer in on one phase and take the lighting all from this transformer, or whether it would be better to have the grounding only on one of the transformers on one phase and have the lighting distributed from the three transformers as is now done. I should like to hear the experience of some of the men in this matter, and get their ideas especially on guying and grounds.

Colonel Betts. In New Jersey one of the largest companies does not ground its two-phase power secondaries at all. The lighting is supplied by separate transformers. They have a regular program of testing transformers to see if there is liability of any danger from lightning, etc. They actually test transformers to find out whether anything has happened to them, so with their system of inspecting transformers the situation seems to be satisfactory. We have not had, in several years, any cases of death or shock that we know of, that have come because circuits have not been grounded.

With regard to the difficulties in establishing grounds, New Jersey has a rocky territory in the northern part. The rules for grounding call for grounding on water pipes. In Bayonne and in Hoboken the municipal authorities were opposed to attaching the grounding systems to water pipes on account of electrolysis troubles that had been caused by street railways. Professor Ganz, of Stevens Institute was very active in bringing about a solution of that matter. The grounds are now being made on the water-pipe systems, which is the only way to do it on a rock ridge. Along the seashore and the territory back of it there is a great deal of dry sand and gravel. There are few water pipes or piping systems which can be used for grounding, and the companies have experimented with ground rods and things of that kind. While we have an order on every com-

pany requiring the grounding, they are often reluctant to put in ground rods because the customers get the idea that they will be absolutely protected. We have been unusually fortunate in not having anything happen, but by stirring around among the companies we have possibly kept them a little more alive in seeing that their apparatus itself and transformers, etc., were located where there was no possible danger of accidents.

Doctor Lloyd. With regard to the problem brought up by Mr. Hayden, I know that has come up in a number of places. Usually the higher voltage power circuits are not required to be grounded under the rules, but where they tap off the line and get 110 volts for lighting or use separate transformers, the secondary wires should be grounded, and wherever these lighting taps have been grounded they have brought up the question as to how it should be done. One aspect of the problem comes up in another case where you have the high-voltage circuits carrying the power and you want to get lighting from the same source. You can put autotransformers in the same circuit and get 110 volts that way. If that happens at a point on more than one circuit you are going to have trouble in grounding. In California they have prohibited the use of autotransformers. They require a two-coil transformer so that the lighting circuit will be entirely insulated from the high-voltage circuit, and ground each circuit for itself. I think probably that particular item would not ordinarily come under the jurisdiction of the utility commission since it is a problem of interior wiring. The consumer connects the autotransformer on the circuit after it has passed his meter. In California the rule comes under the Industrial Accident Commission.

Regarding the other aspect of this matter brought up yesterday regarding the change in the Underwriters' Code, I was just looking over the rules in a number of States and find the cases pretty nearly equally divided. Quite a number require grounding according to the Safety Code, and others have required grounds according to the rules of the National Electrical Code. The two were practically identical a few years ago, but these changes proposed in the Underwriters' Code may bring in a discrepancy between the two sets of rules. I think that this is probably a matter in which you gentlemen are particularly interested, and I should like to hear from some of you, especially in regard to a single grounding connection for both circuit and conduits. It is an important matter and we do not want, if we can help it, to get wide divergence in practice.

Mr. Knowlton. With reference to Doctor Lloyd's statement regarding a single ground connection for both circuit and conduit or noncurrent carrying metal parts, the criterion would be the actual experience of the companies in connection with their routine inspections to determine how frequently ground connections are lost by corrosion or interference. If that experience could be tabulated it would be a fairly good guide to determine the desirability of a change in the rule.

Doctor Lloyd. From the complaints, it appears that plumbers sometimes remove the grounds when repairs are made in house connections, or they are left off, or sometimes interfered with in other ways; we have to take that into consideration. Some attempt should be made, as is done by some companies, to follow up not

only to see that they are attached, but also to see that they make the proper connections. One municipality which has already followed this practice of permitting the common ground connection is in Michigan. I had hoped that Mr. Toeppen would be able to tell us something about that, but apparently they have no record in the State office of what the experience has been in these companies.

Mr. SNOOK. Doctor Lloyd said the other day that the Middle West was more likely to have good driven grounds than some of the other sections. That question is a matter of relative resistance. We find that even the best ground we can make has high resistance unless the top of the ground is wet.

I would like to give an illustration bearing out his suggestion that the ground can be very easily lost. A boy was killed in Columbus about two months ago on a 240–120-volt Edison three-wire alternating-current distribution line. The little fellow was about tall enough to touch the key socket, and all he could get was on the exposed lamp joint in the socket, but it was enough to hold him. His mother picked him off about 10 minutes after it happened. A joint investigation by the fire marshal and the public utility commission showed that there was 240 volts between the place where the boy made contact and ground. It showed a ground somewhere. We found that in order to give service the service man, without consulting any authority, had taken the ground off the neutral at the transformer. This, combined with the house ground, caused the little boy to lose his life. He was perfectly healthy. It should not have happened, but it did. We checked over several transformers and distribution systems in that section and we found two or three where grounds had been lost.

Mr. CRITTENDEN. If there is no more discussion we will pass to the next paper on the program.

THE PUBLIC INTEREST IN HEATING VALUE STANDARDS FOR GAS

By S. A. COVELL, *Assistant Engineer, Maryland Public Service Commission.*

The question of the most desirable heating value standards for gas has been much discussed for several years past. The first standards were adopted when a large portion of the send out of most gas companies was used in open jet burners. These original heating value standards were set so as not to interfere greatly with the use of gas for this purpose. The use of gas for illuminating has come to be a less important consideration in determining the proper heating value standard. This, of course, is due to gaslighting being superseded by electricity and to the almost general use of mantle lights.

Heating value standards have been very generally revised downward during and since the war. These reductions have been made for several reasons—the high price of oil, evidence showing that high standards give rise to complaint and inefficiency in the use of gas, development in the art, such as the more general use of vertical retorts.

THE EFFECT OF A CHANGE OF STANDARDS ON THE CONSUMPTION OF GAS

The usual contention on the part of gas companies applying for a reduction in the standard has been that the increased efficiency of

utilization of the lower heating value of gas would overcome the reduction in heating value. Some of the first investigations made seem to support this contention, but in the light of further investigations the evidence seems inconclusive. Laboratory tests made under working conditions prove that the usefulness of any particular kind of gas is in direct proportion to the heating value. However, in one recent series of such tests results showing consistent and material increases in efficiency with gas of lower values have been obtained. No copies of these tests or details concerning the method in which they were made are available.

Information purporting to show the effect of a reduction in heating value on the consumption of gas per meter is apt to be misleading, and at best should be used with great care. Industrial conditions, rates, the attitude of the consumers toward the company, changes in pressure, weather conditions, and any number of factors have a great effect on the consumption. It is, therefore, extremely difficult to make a test covering the actual use of gas by consumers in any community or number of communities, which will eliminate all the factors tending to affect the consumption except the heating value.

Some of these data have been obtained by reducing the heating value, making a general adjustment of appliances, and comparing the consumption with that which obtained before the reduction. Such tests are also open to the objection that the general adjustment of appliances probably cleared up a number of cases where gas was being used inefficiently prior to the reduction.

When a reduction is made from a very high heating value, such as those corresponding to the old candlepower standards, there may be something in the contention that the gas of low heating value will prove more efficient in so far as the utilization by the consumer is concerned. It is sometimes difficult to get appliances in proper adjustment when operating on a heating value of more than 600 B. t. u. Soot is apt to be given off by the flame. This forms deposits on cooking utensils and mantles, and results in the inefficient use of gas. Walls and ceilings may be blackened.

Another reason why a lower heating value may in actual use prove more efficient is that the average consumer is apt to waste a large amount of gas. Assume a reduction in heating value has been made, the specific gravity and pressure remaining the same as formerly, while the orifices on appliances have not been changed. In such a case gas will be supplied to the burner at the same rate as before, and the amount of gas wasted when the burner is lighted, but not in use, will be the same. The amount of heat wasted, of course, will be less.

A more important consideration is the waste of heat during boiling operations. In this connection the Bureau of Standards recently made an interesting series of tests. In one case they found that it took nine times as much gas to boil the contents of a utensil violently as to boil it gently. It is more or less general practice to waste gas in this manner, and the useful results accomplished in this case with a cubic foot of 500 B. t. u. gas or a cubic foot of 600 B. t. u. gas would be about the same.

The consensus of opinion among gas men seems to be that a reduction in heating value will be accompanied by an increase in con-

sumption. However, it is generally believed that there is some increase in the overall efficiency of utilization of the gas.

Laboratory tests do not take into account the possible increase in efficiency due to the elimination of waste. However, they are, perhaps, the best guide we have as to the effect of a reduction in heating value on the consumption. They prove conclusively that with proper operation of appliances the efficiency of utilization is constant, regardless of the heating value. If we accept this, the heating value, which is most desirable from the standpoint of the public, must be determined by other facts.

THE DETERMINATION OF HEATING VALUE STANDARDS

The general points which must be given consideration in determining the most desirable heating value standard are the economy of manufacture and distribution and the character of service.

Changes in heating value standards as they affect water gas plants.—Carbureted water gas is a mixture of blue-water gas and oil gas. The blue-water gas is made in the generator of the water gas set by the action of steam on the incandescent fuel. It consists mainly of hydrogen and carbon monoxide. The heating value is about 300 B. t. u. The oil gas is made by the destructive distillation of oil in the carburetor of the machine. Its heating value varies, but for purposes of illustration may be taken as 1,700 B. t. u. per cubic foot. The volume of oil gas made per gallon of oil is about 60 cubic feet. If then we use 3 gallons of oil per thousand, the finished gas will consist of 180 cubic feet of oil gas and 820 cubic feet of blue-water gas per thousand. The heating value of the gas will be about 552 B. t. u. If the oil is cut to 2 gallons per thousand, the heating value will be 468 B. t. u. We have reduced the heating value 84 B. t. u. and saved 1 gallon of oil. However, it is now necessary to make 880 cubic feet of blue-water gas per thousand, and the generator fuel will be increased about 7.3 per cent. The steam required by the generator will be increased by about the same percentage. The tar made will be reduced by about 0.15 gallon. The capacity of the machine will be decreased.

The net result is a decrease in the net holder cost of gas per thousand. However, until oil reaches a price considerably above present levels, it will usually be found that the cost per heat unit has increased as the heating value per cubic foot has decreased. This is shown by the following table in which fuel and oil results actually obtained when operating at 550 B. t. u. have been taken. All the facts mentioned above have been given consideration.

Heating value of gas in B. t. u.	Gas oil at 6 cents per gallon		Gas oil at 12 cents per gallon	
	Net holder cost per thousand	Cost per million B. t. u.	Net holder, cost per thousand	Cost per million B. t. u.
400	42.5	106.0	49.0	122.8
450	45.2	100.5	55.2	122.8
500	47.6	95.2	61.4	122.8
550	50.0	91.0	67.4	122.5
600	52.4	87.3	73.5	122.5

In some cases a slightly higher oil efficiency is obtained when less oil is used. Unless the price of oil increases considerably, it would seem that conditions do not warrant a standard very much below 550 B. t. u. for water gas plants.

Changes in heating value standards as they affect coal-gas plants.—In a coal-gas plant the heating value of the gas is practically fixed by the kind of coal used. Most gas coals give gas of a heating value ranging from about 570 to over 600. Some change in heating value can be made by changing the depth of seal, the heats and the time of burning off the charge. Under certain conditions a greater efficiency of manufacture may be obtained.

Exhausting to such an extent that any considerable amount of inert gases are mixed with the gas will, of course, reduce the heating value. It is doubtful if this is good practice, as the works and distribution system must be equipped to handle some inert gas which could be avoided. The presence of large quantities of inerts in the gas may reduce the flame temperature, hence the efficiency of the gas when it is used in mantle lights and in some industrial appliances.

If the heats carried are excessive, naphthalene trouble may be experienced. Another trouble which has occurred in some instances is the excessive corrosion of mains, services, meters, and house piping.

The determination of heating value for mixed gas plants.—The number of plants sending out mixed gas will probably increase in the future. The determination of the proper heating value for such a plant presents a problem which is apt to be different from that of any other plant. For example, in Baltimore the gas company buys coke-oven gas from the Sparrows Point plant of the Bethlehem Steel Co. The supply is sufficient at times to take care of the load. The heating value of the coke-oven gas is about 500 B. t. u. The difference in the holder cost of the coke-oven gas and the water gas is so great that it would be an expensive matter for the consumer to use gas of a heating value higher than 500 B. t. u. One point which should be given consideration is to set a heating value which will permit the most constant proportions of the gases in the mixture.

Pressure conditions.—When a large reduction in the heating value is made it is usually found necessary to ream or adjust orifices of such appliances as linotype machines. Increasing the size of orifices on all appliances should be avoided as it throws an additional load on the distribution system. If there had been no changes in the size of orifices, pressure at the works or centers of distribution and the specific gravity of the gas remains constant, there should be little effect on the pressure conditions throughout the distribution system. If any of these conditions are changed, however, pressure conditions will be affected, and in some cases there is danger of portions of the system proving inadequate. If the rate of flow of gas is constant, the drop in pressure is directly proportional to the specific gravity of the gas.

Consumers' appliances.—In general, the efficiency of appliances is not affected by a reduction in the heating value. The efficiency of mantle lights will be reduced somewhat if the quantity of inert constituents in the gas is increased. A large increase in the per-

centage of inerts may cut down the efficiency of certain industrial appliances where the temperature head is only a fraction of what it is in most appliances.

A more important consideration is the necessity for the adjustment of appliances, so that they will operate properly under the changed conditions. As the heating value is reduced the volume of air required for combustion of the gas is reduced. If the adjustment of the air shutter is not changed, a leaner mixture of gas will pass through the burner. This mixture has a higher rate of flame propagation and the tendency to flash back through the burner ports is increased. In order to avoid trouble appliances should be carefully adjusted when a reduction is made. Probably the most satisfactory method to follow is to reduce the heating value by steps of 20 or 30 B. t. u. and to adjust immediately all appliances which are complained of at any time. There have been cases where proper care has not been taken in making reductions in the heating value. The consumers of such companies have naturally acquired a prejudice toward the low heating value standard.

Experience in England has shown that gas with a heating value of 450 B. t. u. or even lower may be utilized with perfect satisfaction to the consumer.

CONCLUSIONS

The question of determining the heating value standard most desirable from the standpoint of the public is almost entirely an economic one. The standard which should be set is that at which heat can be supplied to the consumer at the cheapest rate. There are, of course, certain service matters to be considered, but unless the heating value is reduced to a very low figure these will usually prove to be of minor importance.

In estimating the saving to be obtained by a change in heating value, the point which should be given the most consideration is not the cost per thousand cubic feet, but the cost per heat unit. It is not sufficient to consider operating expenses alone. Any improvements which the change in standard will make necessary or any reduction which such a change is likely to make in the capacity of the plant should be studied. It should be realized that every plant may present a problem different from that of other plants.

High fuel prices are encouraging the development of new types of gas manufacturing equipment and new operating methods. If the consumer is to get the benefit of savings made possible by such development, heating value standards must be made elastic. Complete gasification plants, the process of steaming in coal-gas plants, extraction of light oils, and a number of other processes may come into general use in the future. The use of such new methods should not be discouraged by inflexible rules.

THE PUBLIC INTEREST IN HEATING VALUE STANDARDS FOR GAS

By C. R. Vanneman, *Chief Engineer, New York Public Service Commission*

Manufactured gas production and gas utilization provide some of the most important problems with which regulatory bodies have to deal to-day. Notwithstanding the fact that the business is a rela-

tively old one, it is at this time on the threshold of an era within which the demands upon it will be enormous, and during which there must be rapid strides in both manufacture and utilization if there is to be not only a satisfied public but also economic operation and distribution. The standards adopted for the control of the heating value furnished are fundamentally important in this development, and I am firmly convinced that the time is ripe for concerted action upon this subject.

In reality public utility regulating bodies, representing as they do both the public and the corporations subject to their jurisdiction, are concerned primarily with the satisfaction of the public, both as to the quality of the gas which is furnished and the price charged for that gas. By satisfaction in the latter case I do not mean necessarily the personal satisfaction of the individual with his monthly gas bills, for that borders on the impossible, but rather the satisfaction that the unit price is not unreasonable. The regulating bodies must also be vitally interested in the methods and practices of the corporations for upon these the price of the gas as well as the future existence of the corporation depends. A poorly managed corporation, even though it comply with adopted standards in furnishing gas, can not do so except at an unreasonable price and a continuation of such conditions eventually results in disaster. Having these things in mind, I would like to discuss one of the principal phases of the gas problem as I see it, which up to the present has received but a limited amount of consideration.

I refer to the ultimate utilization of the gas. Every works manager or superintendent is or ought to be intensely interested in his output, and my observation has been that, generally, he is constantly alive to what is going on within his plant. I realize that there are exceptions, but as a rule, in modern plants at least, I believe this to be true. As to the distribution system, this interest is present, but in a lesser degree, for it is a step removed from his direct observation, and, hence, it does not receive that immediate personal attention which is given to actual production. Still further removed is the utilization of the gas, and here, speaking broadly, the problem is in effect turned over to the consumer, or what is virtually the same, to the manufacturer of the apparatus which the consumer uses. Most corporations sell or are agents for a general line of gas utilizing mediums. How much do the officials actually know about the efficiency of these devices when using the quality of gas furnished by them? I dare say, very little. I am reminded of an assertion of one of the most prominent men in the gas industry in this country, who, in referring to a type of gas range sold by his corporation, alleged that it was as nearly perfect as gas ranges could be made. I have seen many types of gas ranges, but the nearly perfect one, in so far as gas utilization is concerned, has not been shown to me up to the present.

In the recent investigation conducted by the Public Service Commission of New York, it was quite obvious that the utilization phase had been considered in but a secondary light by those who appeared as experts in that inquiry. Even after the completion of this inquiry and the promulgation of an order establishing a new standard, I found that the gas producing corporations knew little about the

efficiency with which appliances, in general, are used; in other words, this has been left up to the manufacturer. The opening of a cock on a gas range permits gas to flow; and if the air shutter is set within certain limits, a flame developing more or less heat is produced when the mixture of air and gas is ignited. Employees adjust the air shutters and pronounce the device efficient, and, perhaps, for years it continues to be used in its original condition. Only upon complaint or under the influence of a highly organized service bureau are any changes ever made. I admit that a device so constructed must needs be held in high respect, but such, nevertheless, does not offer irrefutable proof of the efficiency of the device.

You may ask what this has to do with a heating value standard. For years within the United States, at least, gas ranges have been gas ranges, and here I am referring particularly to the ordinary household type, and not to the more highly perfected hotel or restaurant type. The burners of to-day vary little from the burners of 20 years ago. Then they would handle practically any gas furnished; to-day they do the same; but how do they handle it? Does the consumer get out of the gas burner full value in heating energy for the volume he consumes? I am very much inclined to believe that there is a tremendous annual waste in heat energy due solely to the fact that the varying qualities of gas furnished throughout the country have caused manufacturers of devices to be content to furnish those which would utilize practically any quality of gas. Improvements in appearance, in insulation and the installation of automatic time cooking devices have been rapid within the past few years, but outside of the industries using gas under pyrometric control, there has been little improvement in the direct means of utilization.

A heating value standard, therefore, seems to me to be vitally important from this point of view. If within this country a uniform standard were adopted, manufacturers could immediately concentrate their attention upon the utilization question within the domestic field, in which I include not only cooking but also house warming, a field which I am convinced will within a very few years cause an enormous gas demand.

I do not intend to make any argument as to what value is the best one. This is a matter subject to the determination of the bodies having jurisdiction within that field. I deem it proper, however, to briefly refer to existing conditions, and to recent activities in establishing standards. In New York State after an exhaustive inquiry, during which engineers of prominence in the gas industry were called upon to testify, a standard of a monthly average of at least 537 B. t. u. per cubic foot was adopted. This supplanted a 22-candlepower standard formerly in effect within practically all of New York City, a heating value standard of 525 B. t. u. in a portion of that city, and a heating value standard of 585 B. t. u. which had been in effect in the State outside Greater New York for many years. In California and in Maryland, extensive studies have been made. The former State, according to press reports, is about to consider for adoption a standard of 540 B. t. u.; the latter has, I believe, adopted a standard of 500 B. t. u., at least for Baltimore. In Eng-

land for two years the therm system has been in effect. I find there is still a distinct difference of opinion as to the desirability of such a system. Out of all the discussion, however, I do not find anything to indicate that it may be supplanted. Comments by eminent gas men within England respecting its use are interesting; but all opinions lead to one inevitable conclusion which is summed up in a statement attributed to Mr. G. M. Gill, viz, that the quality of gas decided upon must be that best suited to the consumers and their appliances, and be such as may be produced and sold at the lowest price per therm. Again we find the corollary to the above in the following statement: "Whatever the quality declared there is no alternative, if the service is to be a good one, to the absolute necessity of adjusting all the consumers' appliances to such quality."

Other States within the United States have adopted standards, and Canada has been working for some time under one of the lowest standards. The latest available information indicates that there are no standards in 19 States; that 2 have a standard of 600, 1 of 580, 2 of 575, 2 of 570, 2 of 565, 1 of 550, 2 of 540, 1 of 537, 1 of 539, 2 of 528, 3 of 525, 1 of 520, and 1 of 475. Two other States are now engaged in an investigation which will probably lead to a revision of existing standards, and one State still has a candlepower standard. The fact that 19 States have no standards does not mean that within the borders thereof gas is furnished in all communities according to the dictates of the corporations. On the contrary, certain municipalities have by ordinance adopted a standard for the corporation serving within its boundaries. A notable example is Iowa. The State has no standard, but the city of Des Moines has recently adopted a standard of 560 B. t. u. Such then are the varying standards with which the manufacturer of gas appliances is confronted. Would not a unification of these standards lead not only to the production of a much more efficient line of devices, but what is far more important, to the development of highly standardized gas production apparatus?

As bearing on the foregoing, certain observations which I have made of tests with gases of different heat values seem to be pertinent. These tests while laboratory in character were designed to reflect the efficiency of different heating value standards from the point of view of work performed. One in particular was a direct comparison between gases having heating values of 537 and 585, respectively. The results are interesting. An average of five tests in which identical conditions prevailed, and where correction factors were applied to give positive comparisons, showed that the efficiency of utilization of 537 gas was 46.7 per cent, while that of 585 was 43.2 per cent. As you will expect, the time element varies, but to perform the same amount of work, an increase of but 1.12 per cent in time was necessary in the case of 537 gas.

But with all these results, as the experimenters aptly put it, one could get practically anything desired, because of the existing variables in the devices used. Pyrometer tests, however, showed a higher flame temperature for the lower value gas. Tests in which the distance between the burner and the object to be heated was varied indicated still other results; likewise, in the case of different pressures. No matter what the B. t. u. content may be, the results from the use of the gas will not be constant if there is wide fluctuation in these other

variables. So it is that a universal standard for heating value suggests a universal standard for pressure, etc.

The question of pressure is a most important factor. Existing systems of distribution, laid out as they have been in many cases without due regard for the future, have produced pressure variations which have been difficult to control. Many expedients have been adopted, including pressure regulators, high-pressure feeders, belt systems, etc. All have tended to correct the evils resulting from the initial errors. There is still the peak demand with which to contend, and this demand is the controlling factor in the satisfaction of the public. Inadequate pressure at peak demand results in inadequate service to the ultimate consumer. Too often peak comes during the period when the preparation of the Sunday dinner is in progress. Of course, in the adoption of a pressure standard there are many controlling features which should be considered, which may influence the standard adopted, or even its adoption at all for the time being. I know of instances where the adoption of a pressure standard would be accompanied with extreme hardships, which ultimately would be reflected in the price of the gas. A new system laid out with due regard to demand should not suffer from pressure variations, neither should extensions to existing systems where plant capacity and feeder distribution are ample.

A uniformity in the treatment of the heating value and pressure standards will lead to manufacturers producing gas-utilizing devices which will enable the consumer to receive the maximum of efficiency from the gas furnished, or, in other words, make it possible for the consumer to get maximum value for the money he expends. I have not heretofore considered the price charged for the gas, since it must obviously be a variable; in fact, it is a function of so many variables that one familiar with the subject naturally hesitates to approach it. Nevertheless, if a uniform standard from which the best results may be obtained were adopted, there would be a general unification not only of the devices which use the gas but, as stated before, of those by means of which it is produced as well. In general, however, the price at which gas may be sold must be controlled largely by the standard of heating value.

Another important factor which is important in any discussion of this subject is the acceptability to the public. It has been my experience that notwithstanding the extensive public discussion which a heating value standard has had, especially in the press, it is still an enigma. It even provokes bitter and contentious discussion, and in one instance at least has led to a considerable amount of unpleasantness. The public is inclined to look upon it as another means by which it may be beguiled by alleged avaricious corporations, that it permits of a reduction in the value of service rendered without a corresponding reduction in the ultimate cost to the consumer. For instance, during the period between the adoption of the New York 537 standard and the date on which it was to become effective, one municipality raised the question that the reduction in heating value was much greater than the reduction in price, when compared on a percentage basis; that is, the contention of the municipality was that if a reduction of 8.2 per cent were made in the heating value standard, there should be a similar horizontal reduction of 8.2

per cent in price, where, as a matter of fact, the reduction in price in the particular instance was but 3.6 per cent. Similarly, the public finds it difficult to accept the conclusion that a standard of 528 is proper in Massachusetts, for instance, while just across the line in New York 537 is proper. While I recognize the fact that there are many factors which influence a decision on the standard adopted in certain communities, nevertheless I feel sure that in the interest of the common good, some of these factors now considered controlling should give way to the more important factor of common public interest, from which immediately and directly follows an improved public relationship.

In my treatment of this subject it may be inferred that I have given but little thought to either the production of gas from the corporation's viewpoint or to the process by which the English Government has endeavored to bring satisfaction to the English public. In the case of the former it is my belief that, no matter what the present situation may be with an individual producer, a rational uniform standard can not but inure to his benefit. Concentrated effort directed to the performance of a single task in the best possible manner can not but be productive of the highest results. As to the British expedient, I am convinced that time will show a continued narrowing of the range of B. t. u. standards adopted by the various undertakings, so that eventually there will be but one quality of gas furnished. I do not see how such a conclusion can be avoided. If inevitable, as it seems to me, is it not much better to avoid the difficulties always attendant upon an evolution?

In conclusion, I desire to leave with you this thought. With so many different standards throughout the country, there can be but confusion as to which is the best heating value. With such confusion there can not be crystallization of thought within the industry which will make for ideal conditions in general. With a uniformity of standard there will be a concentration of effort, which must of necessity result in the production of gas of a higher quality from all standpoints, and a development of the means of utilization which will make for increased output, conservation of our natural resources, and ultimate satisfaction to the public.

DISCUSSION OF PAPERS ON HEATING VALUE STANDARDS FOR GAS

Mr. Knowlton. Several years ago we had a request from the Ordnance Department asking us to lower the quality of gas in a certain city. We immediately arranged for an investigation of the gas supplied to some 300,000 population. We tried to arrive at the quality of gas which would give the greatest utilization value to the consumer; that is, the greatest number of B. t. u. of heat communicated to his actual utensils per dollar. In trying to make the test practical, we adopted the type of range and type of burner which this particular company had most extensively sold. The test consisted in raising 5 pounds of water just to the boiling point. We first tried to eliminate the effects of pressure and distance from base of utensil by observing separately what these effects would be and plotting them. To sum it all up, we got the range conditions as practical as we could make them and proceeded to make various mixed

gases and plotted the effects. We found under these conditions that gas in the holder with the highest utilization efficiency in dollars and cents to the consumers should be about 540 B. t. u. per cubic foot. Therefore, to allow a margin for smaller companies with a small output, we set 528 as a minimum.

In reference to Mr. Vanneman's proposal that there be as far as possible a national standard, I do not see any good reason why we should not aim toward that, just the same as the voltage on lamps. The lamp manufacturers no longer make lamps for several voltages. They are built for only a single voltage or at most three voltages. In this gas problem it seems to me that it should be possible ultimately to apply the same treatment.

Mr. COVELL. I feel that the work done by the Bureau of Standards has shown that the efficiency of utilization is practically constant regardless of the heating value of the gas. As to a uniform standard, it seems to me that in gas we have a problem that is entirely different from the electrical problem. I do not feel that the design of appliances varies enough with heating value to make the adoption of any single standard over the entire country, or even over any State, desirable. The standard should be determined from the standpoint of economy of manufacture and distribution for each particular company.

The effect of the design of the appliances is very important. For example, smaller top burners on ranges may improve the efficiency of utilization.

Mr. VANNEMAN. I recognize that there will be difficulties attendant upon the adoption of a universal standard, but as long as you permit this differentiation, just so long are you going to have difficulty. The appliances in use to-day properly adapted will work as well with a standard gas as they do now. Why continue all these variations when you can work toward a common standard?

Mr. HAYDEN. In regard to establishing a uniform standard I have in mind an oil gas plant in Wisconsin which has a heating value of 900 B. t. u. Would not the advance in the art of manufacturing gas be one reason for not going to a definite standard unless possibly we went to a rather low one? It seems to me that might be done. Wisconsin established a minimum of 520 B. t. u., permitting each utility to make its own standard, with the idea that different companies would establish standards which they could maintain most efficiently. Most of the utilities have adopted 520 B. t. u., although there are some with a standard of 545 and 550.

We have observed more or less closely different plants and their output. When the standard was lowered we required each utility to submit monthly manufacturing data. We have tabulated the data, but as yet I have not made a thorough study of it. From observation of that data we have not been able to determine that there has been an increase in efficiency following the change in standard from 600 to 520. I have made special inquiry and have not been able to find in my own gas bill a difference in consumption of gas. Of course, we understand that there is a waste with the higher B. t. u. gas, but it would seem to me that if there was any such difference in the actual use of gas it would be so apparent that you could find it out. I realize that laboratory experiments show it conclusively, but do not believe this principle works out in actual use.

Mr. Crittenden. It appears probable that the discrepancies which have been reported between laboratory conclusions and actual practice where the heating value of the gas has been changed, may be explained by the fact that lamps and other appliances are usually far from having the adjustment which would give the best efficiency. This is, perhaps, particularly true of gas-mantle lamps. In experiments made at the bureau a few years ago lamps of various types were operated with gases ranging from 900 B. t. u. per cubic foot, obtained by enriching with benzol, down to blue water gas. When the lamps were adjusted to the best efficiency for the particular gas used, the efficiencies were practically the same throughout this range. In actual operation, however, lamps are not so adjusted and a change in heating value does not have the effect on consumption which might be expected. Unless special attention is given to the matter the lamps are probably left without any change in orifices so that changes in the amount of gas used are relatively small. Somewhat the same condition applies also to other appliances, such as ranges, where the efficiency of use of the gas depends so greatly on conditions such as distance between burner and the bottom of utensils and on the rate at which heating is done, that a change in heating value of the gas applied can hardly be expected to be immediately shown by any change in consumption.

Colonel Betts. In 1912 New Jersey adopted some rules which are pretty much the same as the Wisconsin rules. When the prices for oil went up a few years back to very high figures and gas oil cost 12 to 16½ cents per gallon, they made some changes in the standard. The standard was supposed to be set at a minimum of 525. A later decision covering the whole State called for an average of 525, and left out anything about variation. I have always been skeptical about this because difficulties come from too great fluctuations, and a particular pressure, or particular heating values have not nearly as much effect on customers' bills as wide fluctuations. However, the order went out fixing a minimum standard of 525. The Public Service Gas Co., selling about five-eighths of all gas sold in New Jersey, had this average of 525, and later on the standard was attacked particularly in Jersey City. To meet the situation we had to open an office of the Public Service Gas Co. in Jersey City and send out a reminder that a representative of the public utility commission was in the office to receive complaints. He received a ridiculously small number of complaints according to the number of people who came to pay gas bills.

The Public Service Gas Co. presented some statistics taken somewhat carefully on consumers' meters in Jersey City and Newark, but taken at random so far as customers were concerned. They were selected to include the customers who had taken gas for several years. The summation of figures for 700 customers showed that if there was any increase in gas consumption it did not exceed 3 per cent. In one case it was 2½ per cent, and in the other it was a little over. You could not tell anything about it.

The use of gas from the standpoint of the effect of heating standard could be classified into three classes—the use for mantle lighting, use for ordinary household heating and cooking, and industrial use where you have apparatus designed by experts. We got into

some trouble and were somewhat embarrassed by broadcasting data not exactly supposed to be public. The results were based on conclusions by the Bureau of Standards in a technologic paper some years ago in which they concluded that decreased heating value of gas meant corresponding increase in the amount of gas used.

The conclusions in that abbreviated form got around and a number of our cities contended that the Bureau of Standards itself had found this to be so and so. On the other hand, I have made the statement that gas of a lower heating value, somewhere around 540 to 550, has a higher flame temperature which actually combined with other things caused an actual reduction in the amount of gas used. This is not a scientific statement; it is more or less a fact, that in connection with gas cooking there are two methods in which heat from gas is applied to the food—appliances in which the flame impinges on the surface of the device and others in which the heat has to pass through the air, like baking, roasting, etc. In devices, such as a saucepan or frying pan, so located with reference to the flame that the flame itself is in contact with the surface of the pan, the higher flame temperature has resulted in an actual reduction in the amount of gas required to produce certain definite results. On the other hand, in roasting, baking and the like, where the heat has to pass through the air, the actual consumption of gas is increased. The results are somewhat mixed. In a house where little roasting or baking is done an actual consumption of gas might be reduced, while in a house where much of the gas is used for roasting and baking, the gas bills would be a little higher. After a study of the bills paid by some 700 customers in Newark and some 700 customers in Jersey City, all of whom had been regular customers continuously for a long period of years, the conclusion was that there was no real indication that bills had been increased because of any change in the character of the gas itself. This, I believe, follows exactly the experience in Massachusetts as reported by the commission.

In regard to the apparatus used in industry under careful control, there would be expected to be a fairly definite increase or a proportionate increase, depending on the gas itself. So far as the mantle burners are concerned, the amount of gas used in illumination has gone down in proportion to the total. The amount of gas used in industries in many of our cities is not so high so that it comes right down to the household use again, and the experience of these 700 customers in each of two cities seems to be the only basis that influenced the board in keeping the standard just what it was.

Mr. VANNEMAN. In New York there was very great diversity of opinion as to whether the companies should come down in heating value by gradual steps covering a long period or by fairly abrupt drops over a short period. A meeting at which that question was discussed resulted in each company doing that which seemed best adapted to its particular needs. In New York City where a candlepower standard has been in effect, the gas corporations decided that they would come down by small steps covering a long period instead of immediately dropping to the 537 standard, whereas up State one company started to come down on the 1st of October and by the 15th were down to 537. That was done without any definite ad-

justment campaign. Necessary adjustments were taken care of in the ordinary regular line of adjustment work. This seems to indicate quite conclusively that adjustments which the ranges had and at which the burners had been set would generally take care of the drop to 537 from 585.

Colonel Betts. Just at the time we made this reduction six companies were petitioning for increased rates, and the difference in heating value was taken into account in a determination of the new rates. Other companies were warned that the matter would be taken care of in time, but not until results were known as to what the decreased heating value had meant to the companies.

Mr. Nexsen. Returning to the question of design and operation, Mr. Covell spoke of the difficulty some companies were having with holders. I should like to ask him if he has arrived at any proper ratio of gas send out to holder capacity.

Mr. Covell. In the cases of two coal gas plants the maximum daily send outs are about four times as great as the holder capacity. That ratio for the operation of these small plants is too low, particularly as the maximum hourly send out is from 12 to 15 per cent of the maximum daily send out. In a plant with a holder capacity of 50,000 and a send out of 200,000 a day, an additional 100,000 cubic foot holder would enable them to get along very nicely. The heating value could probably be reduced from 630 to about 585 B. t. u.

REPORT OF COMMITTEE ON ORGANIZATION

Mr. Hayden made a report for the committee on organization as follows:

It is recommended:

First, because of the valuable information to be gained by personal contact and exchange of ideas, and the possible benefits from greater standardization of regulatory requirements of the various commissions through the influence of the Bureau of Standards, which has done such notable work in this direction, that future conferences of the engineers of the railroad and utility commissions be held at such times and places as may be determined, but that a definite organization be postponed for the present.

Second, that the Bureau of Standards, having thus far acted as sponsor for the present conference, which has proven so profitable, be requested to continue in this capacity; and

Third, that an executive committee be formed with a chairman, who shall be a commission engineer, and a secretary, who shall be from the Bureau of Standards, the purpose of this committee being to provide some responsible body with whom the Bureau of Standards may consult with respect to the carrying out of future conferences.

This report was unanimously adopted after brief discussion, and the executive committee was chosen as follows:

Chairman: C. B. Hayden (Wisconsin).
Secretary: E. C. Crittenden (Bureau of Standards).
Members: C. H. Vanneman (New York).
A. I. Thompson (Oklahoma).
W. M. Black (Maine).

Mr. Wolf. Mr. Crittenden, may I ask the chairman of the executive committee to write to the director of the Bureau of Standards and the Secretary of Commerce thanking them and through them the electrical division of the Bureau of Standards for their fine work in giving us this opportunity to come together for mutual consideration of those problems of interest to all of us.

Mr. Hayden. You have heard this motion made; what is the vote?

The motion was unanimously carried.

Mr. Crittenden. I will call on Mr. Imboden for his paper on natural gas problems.

CONSERVATION OF NATURAL GAS

By James Imboden, *Chief Engineer, West Virginia Public Service Commission*

There has been such an enormous amount of painstaking work done by the Federal bureaus, the State governments, and various associations of producing and distributing companies that I will not offer any suggestions strictly along the lines of use and supply. My thought is that, as State commission engineers, our problem bears on another phase of this subject; that is, the education and the consequent protection of the producers and the public.

The engineering department of the West Virginia Public Service Commission in collecting data on the gas situation in this State and the territory served with West Virginia gas, addressed letters to the engineers of the utility commissions of such States as we believed produced gas. The information furnished by these men shows that in a large proportion of those States lying between the Mississippi River and north of Louisiana, gas in certain districts is a thing of the past and in others is thought of as verging on total exhaustion.

At the present rate of consumption the available gas will be depleted within a very few years to such a degree that transportation by long trunk lines as at present would probably not prove a profitable venture at any reasonable price per thousand cubic feet.

Even to-day there exists a shortage of gas at points close to or even in the producing areas, but it is questionable if this is to any great degree directly attributable to an actual shortage of gas in the sand, although the production per well to-day is much lower in volume and pressure than in former years.

For example, in the year 1910 in the Kanawha County, W. Va., field, the average initial gas pressure in a new well was 500 pounds. In 1922 the average well in the same pool, drilled a proper distance from existing wells, will not show a pressure above 250 pounds. In the Boone and Lincoln County fields a similar statement for 1910 would be 570 pounds, for 1922, 80 pounds; in the Roane County field, for 1910, 975 pounds, and for 1922, 58 pounds. In this latter case too much stress must not be laid upon the remarkable decrease in pressure, inasmuch as the producing sand in that territory is very porous in structure and shallow in depth. As regards a reasonable expectation of the number of cubic feet to be expected from the well, it was not unusual in 1910 for an average well to produce 50,000,000 cubic feet per annum, whereas a well in the same territory to-day

would be considered unusually good if it would maintain a production of 18,000,000 to 20,000,000 cubic feet per annum.

I think there is one fairly logical reason for this shortage in these producing areas. The Great War brought about a condition that made it impossible for the producers to carry on their usual drilling program. During this period there was an unusual population increase in the districts served by natural-gas producers. The war required products from these various territories in the manufacture of which gas is an important item, or, in other words, we had the rather unusual condition of an increased demand for a commodity with a decreased production program. And inasmuch as these war-time prices and conditions are very apparent even to-day, the producers are still far behind in their drilling program.

One happy result of this shortage, however, has been to force certain industries and some domestic users to use a fuel other than gas. There are certain industries in which this has been found impracticable or even impossible. In the Ohio Valley territory we have a large glass industry that at present is dependent upon natural gas. For these factories to change to oil or manufactured gas would require the expenditure of immense sums of money. It is, of course, possible to make glass with other fuel, but it is not possible to make the quality of glass in quantity as at present and at present prices if manufactured gas is used. Every foot of natural gas wasted is, therefore, not only lost to those territories now being served, but will be reflected along many lines, from the car windows in the New York subway to the high-tension insulators in India.

The first thought is that a solution of the problem would be in legislation that would prohibit the use of gas for any purpose other than domestic and essential industrial use, such as glass manufacture, etc., and to limit the manufacture of carbon black to gas-producing areas from which gas could not be transported to advantage, always assuming that such legislation were possible through the assemblies or through the police powers of the various State commissions.

But the thought in my mind is that the most flagrant waste is on the part of the very ones we wish to protect, namely, the domestic user. And it is a serious question whether action by regulatory bodies that tends to keep the price low is an unmixed blessing for the user. No man present is so young but that he can remember when this or that district in the gas area was served at from 5 to 10 cents per thousand cubic feet or even on a flat rate, whereas some of these districts are to-day paying $1 or more for manufactured gas, of one-half or less heating value.

In recent years slide-upward scales have won many converts, and this plan has much to be said in its favor, but on the other hand it is not a cure-all and does not produce a sufficient incentive for saving by the worst user of all, who is the average small domestic consumer.

The various Federal Government bureaus have contributed so much valuable matter along these lines that any suggestions from me would be more or less of a repetition of statements that are now available in printed form, but I do contend that concerted action by the State governments along the lines suggested by the Federal Government would almost seem to be a moral duty.

With many hundreds or thousands of years' requirements of coal in sight, manufactured gas will for the same length of time be available for the large centers, but what of the thousands of small villages that now enjoy the comforts of natural gas which could not be served with manufactured gas at a figure at which it could be bought? Even though electrical developments are such that eventually this last class of user could have electricity, I do not think that the most optimistic electric advocate believes that its possible development will keep pace with the gas depletion. And again, manufactured gas at the present state of development can not be transported in a manner and to a distance as is natural gas. It is also a safe statement to make that electricity, no matter how cheaply produced, can never be transmitted and delivered at any price comparable to natural gas.

The present problem is not only to develop better methods of using gas, but to educate the producer and the user to the use of the now developed economical methods of use. While I feel that the large part of actual waste is by the consumer, I do not lay the whole burden on him. A most necessary factor in the solution of this problem will be to make an incentive to save. At this point I wish to call your attention to the following. A speaker at the 1922 annual meeting of the Natural Gas Association of America in Kansas City raised the question whether or not a sufficient price was allowed in the field, and I am quoting Mr. F. L. Chase, as follows:

> I submit the general proposition that the value of gas in the field should be a price that will afford a profit to the independent producer, and that such price should be considered as a fair price for gas in the field and one that should be taken as a basis for arriving at a price to the consumer. As a primary means of maintaining at all times a liberal gas supply, so long as gas at all is available, I know of no better way than through this means. It will result in a good many cases in a higher domestic rate, but it has been found from experience that most of the troubles arising from gas rates have come from shortages of supply with the resulting discontent and discomfort on the part of the consumer.
>
> If, through such higher field price, the production of gas by independent producers would result in maintaining, so long as gas at all were available, a liberal supply of gas, with a corresponding rate to the consumer, and, if the domestic rate were then successfully attacked and reduced, the gas company could secure some relief through a reduction of the field price, with the proper warning to the public that such action would probably result in a diminished supply of gas and possibly a complete shortage.
>
> Where natural gas has been found in oil fields, until recently the idea seems to have been prevalent that it was wisdom on the part of the gas company to acquire the gas at the very lowest price it was possible to secure it. The oil producer, naturally, was forced to accept whatever price he could secure, if he expected any revenue whatever from his gas.

In certain West Virginia districts that are now producing both gas and oil the gas companies find it necessary to allow their wells to overproduce and eventually flood through the necessity of securing the gas for their transmission lines before the oil companies draw from the gas sands and discharge the gas itself into the air.

A suggestion of rate increase for customer's benefit is, of course, a bold one and subject to bitter criticism, but the fact remains that until an incentive for economy is presented there will be no desire on the part of the general public to effect savings to-day for to-morrow's use.

If a consumer who to-day pays 25 cents per thousand feet were compelled to pay 75 cents for the same gas, he could still, by the use of proper type of apparatus and elimination of waste, hold his gas bill to a figure that would only show a small per cent of increase, provided that to-day this consumer is not using the most economical types of appliances. And it is our honest belief that in the low-price districts such appliances are not used. And even though there actually were a cost increase, the additional price paid would be returned to the community in future years multiplied many times. Unquestionably gas at 50 cents or more can not be used for general heating purposes, but I am frank to say that I do not think that it should be. We think that the best way to bring this directly home is to remember those districts mentioned, where gas was once used without stint and which to-day are paying an equivalent of from $3 to $4 for the same heating value.

Assuming that a price increase is a proper measure to bring about more careful use and general conservation, there must be great care taken to protect the public from shortsighted action by utilities. As an explanation of this I will cite the following: In Kanawha County, W. Va., the rate for gas to-day is 20 cents per thousand feet. Assuming that the utilities were granted a rate of 50 cents per thousand feet, unquestionably Kanawha County consumers would economize. Let us further assume that the present price of 20 cents allows the utility to be assured of a 6 to 8 per cent return on its capital invested, plus an 8 per cent depreciation and depletion reserve. What assurance have the Kanawha County consumers that the utility will not transport the gas that they would be forced to conserve to some other point for sale? In other words, is it fair to put a price on gas in producing areas that will allow the natural gas utilities to compete in nonproducing areas and at the expense of the now existing consumers in producing districts? If this point and other similar problems can be covered by the various commissions, I then say let us increase the price.

Such action would incidentally benefit certain users in the territories now served, in that the various producers would be assured of long corporate life and could then extend their mains to potential consumers in those districts not served at present and could furthermore make many improvements that their systems now demand.

As stated before, without doubt gas is now being wasted in the field. We have in mind a recent report received from a small utility that in seven months delivered approximately 1,260 thousand cubic feet of gas and stated they used 1,000,000 feet in drilling a well. Their gas is sold for 35 cents per thousand and $350 will buy a great deal of coal in West Virginia. Such practice should not be allowed. Indiscriminate drilling for oil in territory served by gas-transport trunks, with no provision made to conserve the gas when encountered, is a criminal waste. We have seen water pumps operated by gas instead of steam, the gas being fed into the steam cylinder and discharged into the air. Of late years electric power has been used to great advantage in drilling operations. Through the courtesy of the H. L. Doherty organization there have been made available to us cost data covering operation in the mid-continent field which have proven beyond doubt that electrically operated drill

rigs are not alone satisfactory from an operating standpoint, but show in a majorty of cases that wells can be drilled cheaper than with gas or oil heated steam boilers or oil engine-driven rigs. In some cases a saving of one-half of former cost has been noted and with an additional time-saving factor. With reference to the adaptation of electric power to the gas-producing operations, it might be noted that uniform or general practice has been to build compressor stations at central points. This means stations in most cases of considerable size.

The result has been that as drilling territory was extended suction lines have become longer. It is possible to conceive that with wells of varying rock pressure connected to a common suction line, unless great care is exercised some part of the work done by the suction engine is equivalent to drawing a vacuum in a spur line into which no gas would flow and with danger of doing damage to the well through water flooding. Our thought is that if electric power, where available were used, isolated motor driven composite vacuum and compressor units could be installed and possibly operated by time switches that would allow the pumping of wells on a time basis directly proportionate to their producing capacity. It is well to note that from an operating standpoint electricity has certain advantages over internal combustion engines in that this last-mentioned type of equipment is very hard of operation in times of low temperature, which times are those when the gas is particularly needed.

Certain States regulate the production of wells to a proportion of their open-flow capacity. A wide divergence of opinion exists among many producers as to the desirability of such rules, but I believe that better control could be obtained through individual compressors electrically operated. I think it is impossible to allow too much credit to the Natural Gas Association of America for their earnest and painstaking work in attempting to organize, standardize, and generally improve producing and marketing practice among member companies and no doubt the greater number of these companies make a real effort to adopt the methods approved by experience or recommended by committee.

But the fact remains that hundreds of producers are not members of this or possibly any other organization and are not profiting by the work mentioned and continue to operate along antiquated lines, and it is this class of operator who should be investigated and regulated by the State commissions. I believe it is a safe statement to make that every commission engineer can call to mind case after case where application for rate increase was made and investigation showed that what was needed by the applicant was not a rate increase or an efficiency expert, but just a little ordinary common sense. We do not believe that the producers as a whole are operating their properties at the highest efficiency, and more than once we have felt that an educational campaign among the producers would not be amiss. With support from the commissioners, engineers employed by the State commissions could do a great deal of good by advocating and enforcing more modern methods in the field.

As the larger part of my work has been electrical, I may have a prejudice in that direction, but I honestly feel that the possibilities

of gas conservation and production through the use of electricity have only been touched.

We think that one of the best things that has ever been said is that what we need is more business in government and less government in business, but regulation of utilities by State commissions has done more to stabilize those industries than any other single factor, and we contend that constructive regulation can not be burdensome either to the public or to the industry. I think the time has come when it is the duty of the gas-producing States to take the bull by the horns and get together on a program that will actually bring about conservation of gas and protect the public. And remember that the public means both the user and the producer, for they are one and the same.

There is a solution of the problem, but it can not be solved by newspaper advertisements, unenforced regulations regarding drilling and transportation, and a general inclination to consider the question as of to-day with no thought of the future. We realize that, as President Denning, of the Natural Gas Association at Kansas City, stated, "much space in publications has been used for educational purposes," but from a personal standpoint, having read a number of these, it is questionable in my mind if they approach the public from the right angle. In most cases the natural inference is that it is propaganda preceding a rate-increase application. In other words, I do not think that the proper groundwork has been done. I feel that in no other industry is personal contact with the consumer so essential as in the furnishing of natural gas, which is a commodity peculiar in itself and in general very little understood by the average consumer.

As a conclusion I will state that my only recommendation is that the various States producing natural gas make an effort to organize through their commissions a committee or board that will act in conjunction with the Federal Government; that the duty of this body will be to prepare and present the actual situation in the various fields to-day; that when this information is completed it be separately referred to the various commissions; and that after separate consideration it shall then be returned to the original committee with instructions to formulate a uniform recommendation for inter and intra state production and marketing of natural gas. It will, of course, be impossible to lay down rules and regulations that will apply to all producing territories, but we do believe that the great problem to-day is to bring about a better understanding between the various commissions which would directly affect all consuming territories.

CONSERVATION OF NATURAL GAS

By Ward H. Snook, *Inspector Power Wire, Ohio Public Utilities Commission*

To appreciate some of the problems which have confronted the State of Ohio in the conservation and economic utilization of the available gas resources, I quote from the annual report of the Public Utilities Commission of Ohio of 1920:

> From the annual reports of all natural gas companies doing business in Ohio, it is shown that during the year 1918 these natural gas companies produced and purchased for consumption in Ohio, in round numbers, 173⅛ billions

cubic feet. Though the demand was greatly increased, the supply was diminished by 9⅓ billions cubic feet, or 5.37 per cent. This diminution in supply is equal to the annual consumption of 1 city like Columbus or 7 cities like Newark or 32 towns like Delaware.

Of the 173⅓ billions cubic feet produced and purchased in 1918, 142½ billions cubic feet were sold to domestic consumers, and 23½ (or 16 per cent of production) billions cubic feet were sold to industries. The remainder was furnished to municipalities or consumed by the companies, or lost in transmission. Of the 164 billions cubic feet produced and purchased in the year 1919, 140 billions cubic feet were sold to domestic consumers, and 21⅓ (13 per cent) billions cubic feet to industries.

In the year 1916 this commission, without any direct statutory authority, but relying wholly upon its police powers, issued its first order directing natural-gas companies doing business in Ohio to disconnect all industries at all times when the weather was such that the supply was needed for domestic consumption, thereby pioneering the way in conserving natural gas. This administrative order No. 34 has been renewed with still further restrictions annually since 1916 and has been pretty generally observed, so that the gas sold to industries was for the most part supplied during summer months, when, if it had not been so sold, much of it would have been consumed by industries of other States drawing their supply from the same fields.

At least 60 per cent of the gas consumed in Ohio comes from the counties of Harrison and Lewis in the State of West Virginia, and that State and the State of Pennsylvania are drawing from the same fields; and from the testimony on file in this commission it is shown that the carbon companies of West Virginia alone drew from this field, during the fiscal year ending June 30, 1917, 11 billions cubic feet; in 1918 nearly 20 billions cubic feet; and in 1919, 19 billions cubic feet.

In hearing No. 1770, held before this commission in November and December, 1919, to determine the status of the natural-gas situation, Mr. J. A. Bownocker, State geologist, and professor of geology at the Ohio State University, testified in substance:

> That for 25 years he had made a study of the natural-gas situation in Ohio and West Virginia; that he had made recent tests of the rock pressure of typical wells in the Reserve field in Harrison and Lewis Counties, West Virginia, from which Ohio draws its chief supply; that whereas the rock pressure in this field was originally from 900 to 1,000 pounds per square inch, it was then but 134 pounds per square inch, and that the field is being rapidly exhausted.

In hearing No. 1907, held before this commission February 27, 1920, Kay C. Krick, vice president of the Logan Natural Gas & Fuel Co., which supplies approximately 100 communities in Ohio, testified:

> That as of November 1, 1919, the available supply of the Logan Company was 88,000,000 cubic feet per day, and that its normal cold weather demand for purely domestic consumption was 135,000,000 cubic feet per day. That the company owns 800 wells in Ohio and had two-fifths interest in the output of 750 wells of the Reserve Gas Co. of West Virginia; that no industries were supplied during the winter months; that new wells produced less than one-third of the quantity of gas produced by former wells. That during cold weather, with all available gas turned on, the company could not meet the domestic demand and that all regulators were so set as to distribute the supply evenly, regardless of the difference in price paid in different localities.

In order to check the depletion from the data at hand, we may assume with practically no error, that the expansion of the gas underground is at constant temperature; that is, isothermic expansion. In other words, the absolute pressure times the volume of the gas is equal to a constant depending on the character, times the quantity of the gas times the absolute temperature ($PV=MRT$). There are two major errors in the assumption that the volume is constant. This can not be true because the wells fill up; this, of course, reduces the volume. However, at the higher pressures the

gas is more soluble and as the pressures are reduced and the volumes are reduced the gas in solution is released.

We find in checking the rock pressures and the volumes of gas actually produced on this assumption, that they check with a fair degree of accuracy. We are, therefore, warranted in assuming that the depletion in 1919 is somewhere in the neighborhood of 80 to 90 per cent. The following tables have been prepared from the testimony submitted by Prof. I. C. White, for 22 years State geologist of West Virginia, and a recent statement of the West Virginia commission showing production for the years 1912 to 1921:

TABLE 1.—*Depletion of natural gas*

Year	Average rock pressure in pounds per square inch	Yearly production in thousands of cubic fect	Percentage of maximum production, 1916	Estimated per cent of gas in terms of 1905
1905	930	----------	----------	100.0
1908	791	----------	----------	85.5
1911	681	206,890,576	69	74.0
1912	----------	239,600,682	80	----------
1913	530	245,453,985	82	56.7
1914	434	236,480,175	79	47.2
1915	379	244,400,183	81.5	40.7
1916	310	299,313,307	100	34.5
1917	241	289,698,967	96.6	27.2
1918	172	280,289,004	93.5	19.8
1919	----------	219,886,837	73.5	14.2
1920	----------	221,266,699	74.0	----------
1921	----------	167,227,696	55.7	----------

An estimated average of from 7 to 8 per cent a year was used from 1911 to 1919. Quoting further from the 1920 report:

> There is a case now pending in the Supreme Court of the United States in which the State of Ohio is contesting the validity of an act of the Legislature of West Virginia, requiring service to the consumers of that State in preference to consumers in other States. Should this act be held valid it would sound the death knell of natural-gas service in most of the communities of Ohio now served from that field.
>
> The commission has deemed it prudent at this time to place these facts before the public in order that consumers may not be deceived by those who ignorantly or purposely attempt to mislead them and in order that they may be apprised of the necessity of preparing for the use of other fuel when natural gas is no longer available.
>
> The commission also appeals to all consumers of natural gas to assist in every way within their power to conserve the present diminishing supply, to the end that service may be extended as long as possible.

This indicates that the Ohio Public Utilities Commission is fully alive to the magnitude and importance of this problem to the people of Ohio, and to the end that the available natural gas resources may be economically conserved, they have adopted the policy of shutting off the industrial consumer at the times of maximum demand and have also graded the consumers, especially the industrial consumers, so that the load may be reduced in such a way as to cause the least disturbance, in administrative orders 34 and 46. They have also limited the domestic consumer at the times of maximum demand to a total consumption of 10,000 cubic feet per month, and in order to

still further conserve the ever diminishing supply of natural gas, they have authorized the companies supplying this service to charge a sliding upward scale. A typical gas schedule of this kind is shown in that of the Athens Co., which is as follows:

Filed November 20, 1919, effective December 20, 1919, and being for each municipality, P. U. C. O. No. 6 cancelling P. U. C. O. No. 5 carrying the following rates: 48 cents per 1,000 cubic feet for the first 5,000 cubic feet each month; 53 cents per 1,000 cubic feet for the next 5,000 cubic feet each month; 58 cents per 1,000 cubic feet for the next 5,000 cubic feet each month; 63 cents per 1,000 cubic feet for the next 15,000 cubic feet each month. Subject to a discount of 3 cents per 1,000 cubic feet if paid within 10 days after the bill for the previous monthly reading period has been issued.

Minimum charge.—The price of 2,000 cubic feet at the rate first above mentioned.

This schedule brings out another point worthy of consideration, namely, that of the minimum charge. This provision is not an economical one, because it encourages the small user to waste his gas up to the amount of minimum charge. For that reason it is not to the public's best interest and should be replaced by a service charge.

Another typical schedule is that of the Lima Natural Gas Co., which is as follows:

For the first 5,000 cubic feet per month $1 per 1,000 cubic feet.
For the next 5,000 cubic feet per month $1.05 per 1,000 cubic feet.
For the next 5,000 cubic feet per month $1.10 per 1.000 cubic feet.
For all over 15,000 cubic feet per month $1.15 per 1,000 cubic feet.
Minimum charge.—$1.25 per month.

Lima is the center of the northwestern Ohio oil and gas field. The commercial supply of gas, however, has been exhausted.

This case is interesting because there is almost a half million dollars invested in 60 miles of high-pressure transmission line for which there probably will be no economic justification when the natural-gas supply shall have been exhausted. This, together with several other items, has raised the price of gas in this case to about the maximum at which natural gas can be economically delivered and sold.

There are minor practices and customs which have grown up with the natural-gas industry, which are very wasteful and in the aggregate cause an enormous wastage. It was customary in the original lease to supply the leaseholder with all the gas he wanted for domestic purposes. There is then no incentive for the leaseholder to install fixtures or economical apparatus, nor to keep the leaks out of his service lines, etc. His yard is quite likely to be illuminated by a torch which is simply a pipe on the end of which the gas is burning. This condition has rather a perplexing legal side, due to the fact that the contracts for the most part were made before the present public-utility law was passed, and consequently were not contrary to law or public policy at the time the contract was made, and the old principle that "you can not impair the obligation of contract" holds in these cases.

It has been suggested by Mr. James Imboden, chief engineer of the West Virginia Public Service Commission, that to a large extent, this difficulty may be adjusted by the gas-producing company

making a new contract with the leaseholder giving him a rather liberal estimate on his consumption and paying him the regular field rate for the saving which he makes on the estimated or contract amount, thus making it well worth the leaseholder's while to conserve the supply.

There is another type of minor wastage which in the aggregate is considerable. This is due to the contract made by the pipe-line company in securing its right of way, which provides that it will furnish the property owner with gas provided he will install the necessary service, reducing apparatus, and meter. In most cases, the installations were made with pipes of inadequate size, many of them being old and in bad condition. It has been suggested that this might possibly be taken care of by the gas company filing with the commission a reduced rate for this class of customer, providing the consumer would rearrange the service so that wastage would be metered and the condition of the installation consequently reflected in the amount of gas consumed.

There is another point which inevitably presents itself. During the summer months the domestic demand falls off and the gas company is unable to maintain its plant on a profitable basis. For this reason the gas company invariably asks for a commercial rate which will permit them to sell their product during the months of minimum demand. While it may seem that putting the commercial consumer who will use enormous amounts of gas on a lower rate and a rate which will compete with other cheaper fuels, is not conducive to the conservation of the supply, yet it is also true that if the gas utility is not allowed to sell commercial consumers to flatten out its load characteristics and keep its plant busy, that the cost to the domestic consumer will be excessive in order to take care of the necessary maintenance and depreciation.

In order to get an idea of the financial status of the gas industry in the State of Ohio, we quote from the 1912 and 1921 annual report of the Ohio Public Utilities Commission. In 1912 there were 485,509 gas customers in the State of Ohio; in 1921 there were 905,567, or an increase of 87 per cent. In 1912 the average monthly bill per customer was $4.10 per month. In 1921 it was $7.26, or an increase of 77 per cent. In 1912 there was an investment per customer of $226.93; in 1921 there was an investment per customer of $370.80, or an increase of 63 per cent. In 1912 the gas companies paid 2½ per cent on their capital investment and 3.2 per cent on their capitalization. In 1921 they paid 6.4 per cent on their capital investment and 8.4 per cent on their capitalization.

Figure 1 shows the trends of Ohio utility rates. This curve is interesting for it shows the relative trend of public-utility rates as well as the average variation of commodity prices. The heavy black line shows the maximum rates allowed by the Ohio Public Utilities Commission in their formal cases. The average of these formal cases is the heavy broken line. The average per cent rate increase of the 100 gas companies, the light broken line, shows that the average increase in gas prices has been greater than those of any other type of utility; the other line labeled "Large telephone companies rates" compares very favorably but does not reflect the average trend.

Let us consider for a moment how far we should go in the conservation measures. There are certain fundamental economic laws which can not be disregarded. It is impossible to adopt effective conservation measures which will conflict with these fundamental conditions, and the point at which conservation ceases to be effective is that point at which it ceases to pay. That point is to be found where an economical substitute may be found, and such substitute we have in artificial gas.

Although Ohio is unfortunate in not having any high grade gas coal, in spite of this fact, by means of a mechanical cleaning process, coals can be treated for a matter of about 15 cents per ton in such a way that we can make high-grade gas and metallurgical coke out of

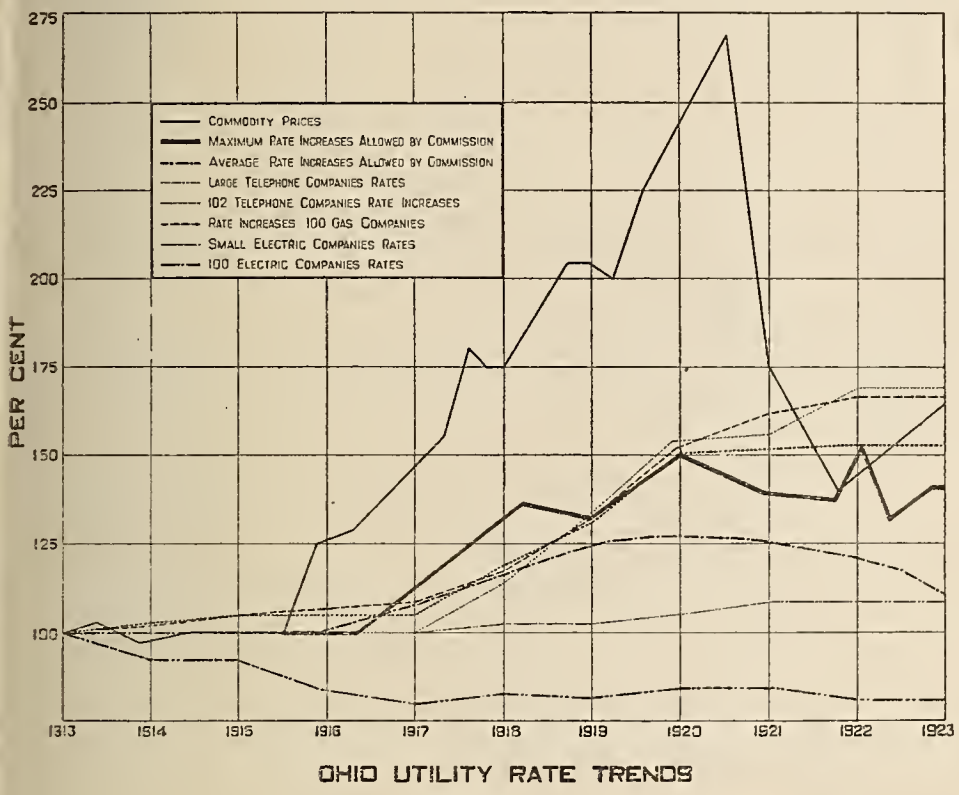

FIG. 1

it. If the local market is such that the coke can be sold for $2 per ton more than the price of coal delivered at the retort, gas may be put in the container at 30 cents per thousand cubic feet. In view of the above we are in Ohio on the verge of an enormous development in the gas industry, especially in the retort processes.

Natural gas should be displaced as rapidly as possible by manufactured gas plants using combination coal gas and water gas plants to effect complete gasification of the coal, using natural gas only as an enricher as we use oil. Enough of the natural gas would be needed to bring the B. t. u. value of the mixed coal gas and water gas, which will be about 400 B. t. u. per cubic foot, up to about 550 B. t. u. In my opinion this is by far the most economical and logical way to conserve our natural gas.

Another kind of conservation which should be mentioned, although it is properly a field of its own, is the application of the gas and its use in fixtures so designed that they will be efficient over the probable range of gas pressure at which they will be required to operate. There are two other principles which might profitably be utilized in the conservation of fuel. One is the thermostatic regulator which regulates the temperature within certain well defined limits; this can be used in domestic appliances as well as in the commercial application, such as in annealing and carbonizing operations. The other principle is that of heat insulation, which has already been commercialized in the so-called fireless cooker.

(On account of the lateness of the hour, the discussion of these papers was not extended. It was pointed out that manufactured gas must be provided to supplement or replace natural gas in the territory which used to be the center of the gas and oil business, while immense new supplies have been developed in more remote locations. This change involves far-reaching readjustments in the location or the methods of industries dependent on gas, and also gives rise to difficult technical problems in regard to service requirements and financing in the regions where natural gas is failing. While it is too late to do much for many of these sections, they afford lessons which should not be overlooked in dealing with the gas supply in other States.)

At 1.45 p. m. the conference adjourned sine die to give members an opportunity to visit some of the laboratories of the bureau during the afternoon.